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The Journal of Thoracic Surgery

VOL. 4 FEBRUARY, 1935 NO. 3

Announcement

WITH this issue the JOURNAL OF THORACIC SURGERY enters a new phase. During the first three years it appeared under exclusively American auspices. Now it is a pleasure to announce that an Advisory Editorial Board representing the Society of Thoracic Surgeons of Great Britain and Ireland has been added to the American board. An invitation was sent to the members of the British Society inviting them to join forces with us and to recommend representatives of their Society to serve on an editorial board. The distinguished surgeons selected, Mr. H. Morriston Davies of Ruthin, North Wales, Mr. J. E. H. Roberts of London, and Mr. A. Tudor Edwards of London, need no introduction to any one interested in thoracic surgery in America. All of them have been pioneers in the development of this special field, and their work is well known on this side of the Atlantic. We welcome their willingness to serve in the capacity of an Advisory Editorial Board, and we hope that their friendly gesture of cooperation will be one more indication that science recognizes no national boundaries.

THE EDITORIAL BOARD.

Original Communications

A CASE OF PRIMARY CARCINOMA OF THE LUNG*

Report Four Years After Lobectomy

C. I. Allen, M.D.
Detroit, Mich.

IN THE past three years there have appeared in the literature approximately one hundred and fifty papers dealing with primary carcinoma of the lung. A fair number of these have dealt with the clinical features; whereas only a short time ago most of the writers were concerned primarily with the pathologic picture. This increased clinical interest is very evident. Reports of patients treated during the past few years have demonstrated that in some instances primary tumors of the lung are operable. As this fact has become accepted, there have appeared papers which have considered the various types of operative approach for removal of tumors, various types of anesthesia and the method of administration, the advantages of the one- and two-stage operations and the value of preliminary pneumothorax as a means of stabilizing the mediastinum. These are milestones which we may look upon with a great deal of interest and with some satisfaction, for they mean that at least an attack has been started against a condition which was, until so recently, considered as absolutely beyond help. Nor need we feel that this recent enthusiasm is misplaced. The frequency of carcinoma of the lung is such as to demand that aggressive measures be taken.

There are many questions which experience alone will answer. The problem of anesthesia is being solved. Both intratracheal insufflation and gas administered with a tightly fitting mask have proved quite satisfactory. Spinal anesthesia has been used in thoracic operations and may find a wider field of application.

The site of operation will, to a large extent, be determined by the location of the tumor. It is quite apparent that extensive rib resections will, to a certain extent, be curtailed as reported operated cases indicate that sufficient exposure can be obtained by less extensive procedures.

The treatment of the bronchial stump offers a field for further study. Electrocoagulation has been used but is objected to by some. Careful,

*From the Department of Surgery, Henry Ford Hospital.

Read by title at the Seventeenth Annual Meeting of the American Association for Thoracic Surgery at Boston, May 31, June 1, 2, 1934.

atraumatic suturing of the mucous membrane would seem to be a sound procedure. Ligation and burying of the bronchial stump in adjacent pulmonary or mediastinal tissue have proved satisfactory both experimentally and in clinical work.

The methods of handling the thoracic dead spaces following pulmonary resections, have been discussed in recent papers. Obviously in some instances no special considerations need be given, as expansion of the remaining portions of the lung will reasonably quickly obliterate the space. The production of a diaphragmatic paralysis will reduce it, as

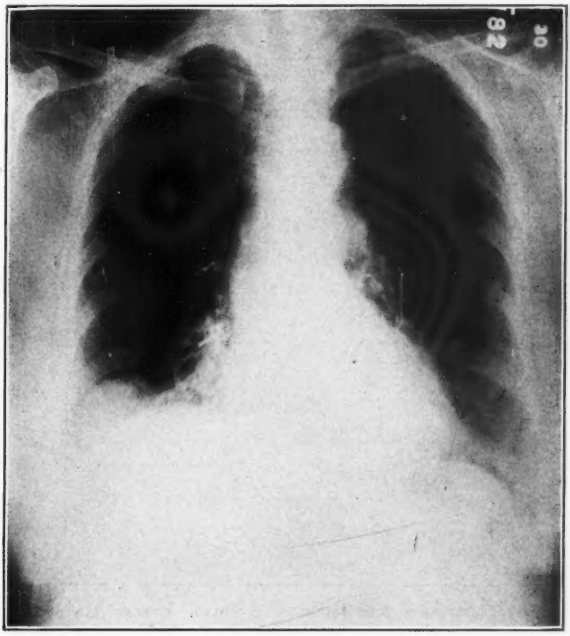

Fig. 1.—X-ray plate taken May 5, 1930. The tumor mass may be seen at the right base directly above the diaphragm.

will also a mediastinal shift to the operated side. Certainly if this occurs, it must be allowed to occur very gradually else we bring on the symptoms which we take such great precautions to prevent during operation. Thoracoplasty, either partial or complete, will undoubtedly at times be necessary. Finally, the acceptance of a permanent, sterile pneumothorax may in some instances prove entirely satisfactory.

From this wealth of information which is being assembled, some definite and what will probably be generally accepted principles in the treatment of carcinoma of the lung will be arrived at, just as has been done in the treatment of malignancy elsewhere.

CASE REPORT

The patient, A. S., Case No. 147182, concerning whom we are making a further report, was operated upon in June, 1930, at the age of sixty-five years. A circumscribed tumor of the right lower lobe was found and a right lower lobectomy was done in two stages. Primary healing occurred, and there was no bronchial fistula. The tumor, on cut section, measured about 2.5 cm. in diameter and grossly was quite circumscribed. Microscopically, it was diagnosed as a primary carcinoma of the lung, of the undifferentiated cell type. There was also found to be microscopic invasion of the surrounding tissue.

Up to the time of our previous report (Allen and Smith) she had remained well and free of any signs or symptoms suggestive of recurrence or metastases, two years following operation.

Fig. 2.—Showing right lower lobe following removal. Cut section of the tumor may be seen.

In November, 1932, two and a half years after operation, she was recalled for a check-up of her condition. At this time she stated that for the preceding four weeks she had had an annoying cough, at times paroxysmal in character, with which there was some mucous expectoration which was occasionally slightly blood streaked. Otherwise, she had continued to be quite well and to carry on with her housework. She had lost no weight. On physical examination, there was nothing unusual found except the evidence of pleural thickening at the right base and the continued elevation of blood pressure, the systolic pressure being 190 and the diastolic 95. Bronchoscopic examination was done under local anesthesia, and a small fungating mass was found in the wall of the stump of the right lower bronchus. A small bit of this, which was removed, showed it to be composed of the same type of cells as the primary tumor. We therefore advised the implantation of radium, and this was done, a dosage of 120 milligram hours being given. A month later, bronchoscopy was repeated. At this time the granulating mass had disappeared leaving a scarred

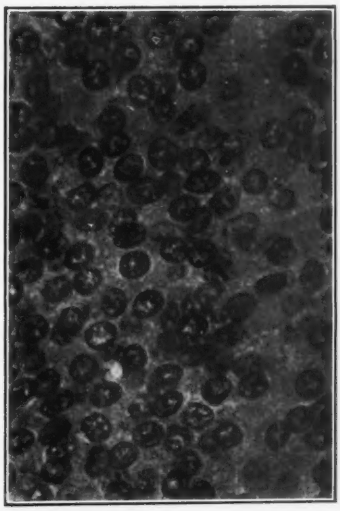

Fig. 3.—High power microphotograph showing the character of the individual tumor cells.

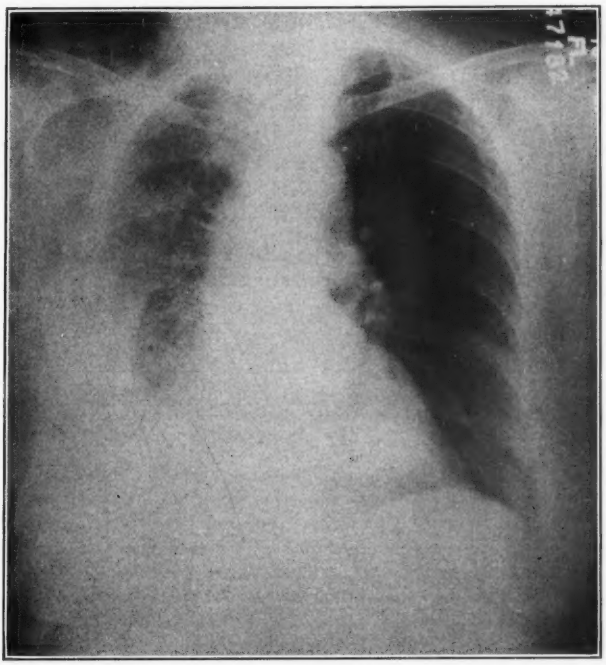

Fig. 4.—X-ray picture taken Feb. 10, 1931. There is a dense hazing over the entire right chest most marked at the base. The hilus shadows are about the same as in the earlier films.

appearance. There was no evidence of bleeding. Meanwhile, there had been considerable improvement, so far as the cough was concerned.

In May, 1933, three years after operation, she was again recalled, and she reported that she had remained quite well. She had carried on with her work, was strong, and had lost no weight. The cough had stopped, and there had been no more blood-streaked sputum. Physical examination revealed no evidence of metastases. There was no weight loss. The blood pressure continued elevated. X-ray pictures of the chest showed no changes from those previously taken. A bronchoscopic examination was made, and a small red area could be seen at the site of the previous radium implantation. It was raised very little and no specimen could be obtained. However, one radium needle was implanted and 60 milligram hours were given.

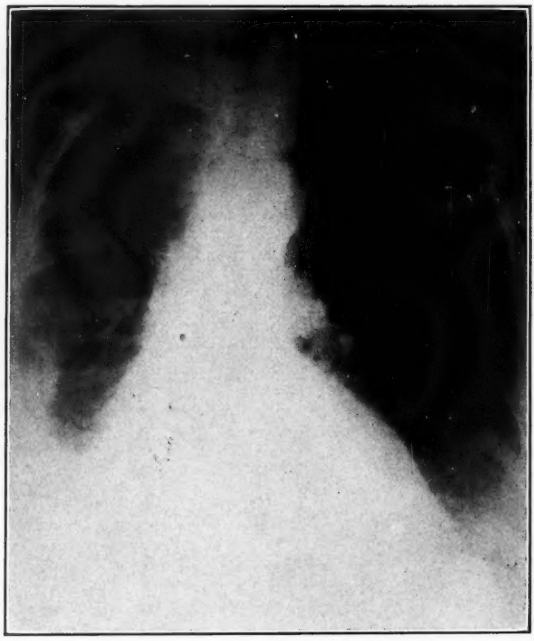

Fig. 5.—X-ray plate taken May 10, 1934 showing persistent hazing on the right side most marked at the base. No essential changes could be made out in the hilus shadows.

In November, 1933, three and a half years after operation, she was again recalled. She had continued to be well except for some dyspnea on exertion, which was attributed to a mild grade of myocarditis. She had, however, during the previous few weeks, had a little expectoration of blood-streaked mucus, and she described it as coming from the nasopharynx. On examination, the chest findings were the same and the blood pressure was still elevated. X-ray examination of the chest was essentially the same as previously. Bronchoscopic examination was made. No bleeding area could be found. There was a small area in the stump of the bronchus which bled on manipulation with the instrument and accordingly, two ten-milligram needles of radium were inserted and 140 milligram hours of treatment were given. No specimen for microscopic examination was obtainable.

In May, 1934, four years after operation, she was again recalled. During the spring she had had influenza, from which she had been slow in recovering. Otherwise she had been well. She had had no cough and no blood-streaked sputum. On examination she was found to have a chronic pharyngitis and maxillary sinusitis which cleared up under treatment. X-ray examination of the chest revealed no essential change. A bronchoscopic examination was made and a small grayish, slightly raised area about 0.5 cm. in diameter could be seen in the stump of the bronchus. A small bit of this was removed, and again it was found to be made up of the same type of cells as those constituting the original tumor. Radium needles were again implanted, and she was given 160 milligram hours of treatment.

In summary, then, we are presenting a report of a woman now sixty-nine years of age, who was operated on four years ago, a right lower lobectomy being done for primary carcinoma of the lung, the diagnosis having been previously arrived at by a biopsy through the bronchoscope.

Two and a half years after her operation, evidence of a persistence of the tumor was found in the wall of the stump of the bronchus and radium was implanted.

Since that time, she has been seen at six-month intervals, and each time radium has been implanted, a total of four hundred and eighty milligram hours having been given.

Clinically, this patient is well so far as the carcinoma is concerned. In spite of her great dislike for bronchoscopic examinations, she has been most cooperative. Even though it has been pointed out so frequently of late, I believe we are justified in mentioning again the absolute necessity of bronchoscopic examinations if one is to have accurate information concerning the condition present.

In the face of the evidence of persistence of the tumor, one of course cannot be too hopeful as to the ultimate prognosis. The fact remains, however, that the patient is clinically well four years after lobectomy and one and a half years after evidence of recurrence was discovered. It is planned to continue with frequent observation of the patient.

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TOTAL REMOVAL OF THE RIGHT LUNG FOR BRONCHIECTASIS*

ESKE WINDSBERG, M.D.
PROVIDENCE, R. I.

THAT life is compatible in man with only one lung is evidenced by the reports of cases of congenital absence of an entire lung.[1, 2, 3] As pointed out by Haight,[4] the experimental removal of an entire lung in rabbits was performed successfully in 1881 by Gluck. Heuer and Dunn,[5] and Heuer and Andrus[6] demonstrated in dogs that shortly after the removal of one lung the remaining lung enlarged and eventually filled the entire thoracic cage in from four to six weeks. The heart is displaced and comes in contact with the lateral thoracic wall. The immediate respiratory needs of the animal are supplied by a functional compensatory mechanism in which the circulation and respiration play a part. This precedes the comparatively late anatomical changes in the remaining lung.

Sauerbruch,[7] in 1923, inadvertently, while removing a large ganglioneuroma, ligated the left primary bronchus and the bronchial artery. The entire lung was cast off ten days later; the patient recovered without a bronchial fistula. This proved that in man an entire lung could be removed successfully, and a primary bronchus could be closed permanently.

The first successful case of total pneumonectomy in man, deliberately carried out, was performed by Nissen,[8] in Berlin in 1931, for bronchiectasis involving the entire left lung. According to Haight,[4] the case reported here is apparently the second instance of successful total pneumonectomy in man. Successful cases have recently been reported by Haight,[4] for bronchiectasis; by Graham and Singer,[9] for carcinoma of the bronchus; and two cases by Rienhoff,[10] for newgrowth. The case reported by Graham and Singer is the first one in which an entire lung has been deliberately removed at one stage, and is the first time in which an entire lung has been successfully removed for a carcinoma.

REPORT OF CASE

R. D., a girl, aged twelve years, was admitted to the Miriam Hospital on August 24, 1932. (Case No. 6636.) She was well until the age of five and one-half years. Then, early in 1926, she contracted measles; this was complicated by bronchopneumonia. The acute symptoms subsided gradually, but a low grade fever, cough, and expectoration of massive amounts of foul smelling sputum have continued ever since.

*Received for publication June 5, 1934.

Except for four brief intervals, she was confined to hospital care from April, 1926, until December, 1932, in seven different institutions.

The sputum often reached a maximum of 350 gm. per day, and amounted usually to 125 gm. with routine postural drainage. There was occasional blood streaking. Dyspnea occurred on moderate exertion. Smears and guinea pig tests of the sputum were negative for tuberculosis on several occasions.

X-ray studies of the lungs demonstrated increased density in the shadow of the entire right side of the chest, most marked at the base. The heart and trachea were displaced markedly to the right. Multiple

Fig. 1.—Lipiodol injection before operation, outlining the bronchial tree in the good (left) lung. Here are also seen the deviation of the trachea and heart to the right, and the absence of all normal lung markings in the right lung field.

fluid levels, changing with the shifting of the patient's position, were seen. On several occasions, probably when the right lung was filled with secretions, there appeared such dense clouding from apex to base that all the lung markings on the right side were obscured.

Bronchoscopy by Dr. B. Sharp revealed stenosis of the right main bronchus. An attempt to inject lipiodol into the right bronchial tree failed on four occasions, except for a small amount which entered what appeared to be the beginning of the middle lobe bronchus. Lipiodol visualization of the left lung demonstrated it to be in healthy condition.

Dr. Alex Burgess, who had seen the patient in previous years, was

called in consultation. In view of the long standing history, with no evidence of improvement, and with some evidence that the patient's condition was gradually getting worse, it was agreed that some form of surgical therapy should be carried out. Pneumothorax preliminary to operation was attempted. The needle encountered gristly resistance; a free pleural space could not be demonstrated on account of adhesions.

On September 10, 1932, the first stage of the operation was undertaken; avertin was used, supplemented by nitrous oxide. The right lung was exposed in the axilla. The axillary portions of the fifth, sixth, and seventh ribs were resected subperiosteally. The intercostal bundles below the fifth and sixth ribs were excised. The pleural layers were adherent throughout, but not very firmly. It was noted that the parietal pleura was quite thin and smooth, while the visceral pleura was fibrotic and thick. The lung tissue appeared hepatized. The diaphragm was high and adherent. With a cherry-red cautery (soldering iron) the lung was burned into. The cauterization was extended, not deeply, but in an ever widening circle, as described by Graham,[11] opening up several pools of pus. The lining of the pus cavities was smooth and thick, and the surfaces appeared unbroken. The parenchyma was indurated and fibrotic. Multiple draining bronchial sinuses were created. Hemostasis was attended to, and the wound was packed with vaselined gauze. The postoperative course was uneventful. Drainage from the wound was profuse, and frequent dressings were required. The discharges soon lost their foul odor and became thinned out. Lipiodol was injected through the draining bronchial sinuses. X-ray studies now disclosed multiple small rounded cavities filled with the contrast medium; these were largely in the center of the chest, with several isolated cavities extending posteriorly.

October 3, the wound was enlarged by removing posteriorly additional lengths of the fifth, sixth, and seventh ribs. The lung tissue lying superiorly and posteriorly was subjected to cauterization. Avertin and nitrous oxide were used. The postoperative course was unusually smooth. Necrotic lung tissue was noted as slough on the dressings. There were many draining sinuses, and the discharges were moderate in amount and free from offensive odor. Expectoration was still considerable.

October 26, the cauterization was extended posteriorly and toward the mediastinum. The lung tissue had to be separated from the pericardium by means of sharp dissection. The heart now fell back to a more normal position in the left side of the thorax. The lung tissue which was thus mobilized was cut away. Respiratory embarrassment occurred toward the end of this operative procedure. Immediately after the wound was packed with vaselined gauze, however, this difficulty was overcome. Postoperatively there was considerable drainage; the amount of expectoration was distinctly less for the first time. On October 29, 250 c.c. of citrated blood were given to the patient by transfusion.

On November 8, 1932, the definitive operative procedure was carried out. Avertin was used and was supplemented with nitrous oxide administered intratracheally. What remained of the right lung was rapidly and carefully mobilized from the mediastinum, the diaphragm, and the entire sweep of the parietal pleura. The parietal pleura was surprisingly of normal smoothness from apex to base. There was no difficulty in separating the lung tissue from the chest wall. The adhesions to the diaphragm, and those to the pericardium which had reformed, were very firm and had to be separated by means of sharp

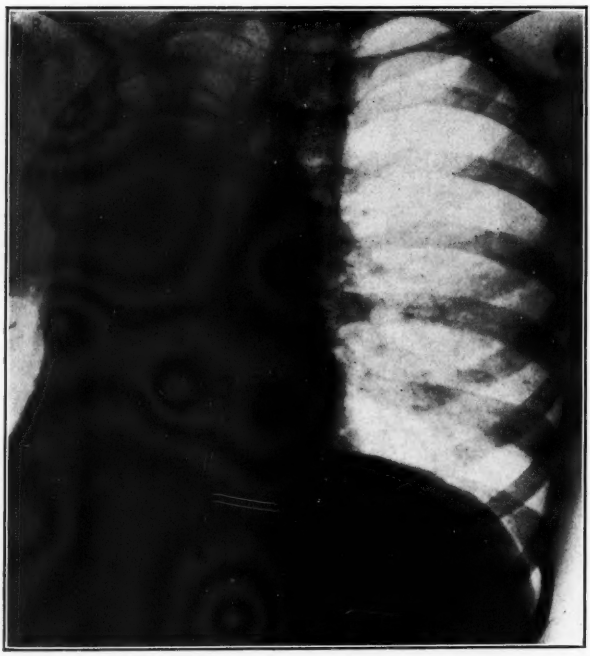

Fig. 2.—X-ray picture taken several months after operation, showing increase in the deviation of the trachea and mediastinum to the right. Lipiodol is seen in the sinus which leads directly to the trachea. Note the absence of all lung markings on the right side.

dissection. The hilum of the lung was cleared all around, transfixed, and doubly ligated with braided silk as close to the trachea as possible. The lung was now amputated at a point about one-half inch distal to the ligature. The remaining stump presented the main stem bronchus and the beginning of the upper lobe bronchus. The pulmonary vessels were individually secured with No. 2 chromic catgut. The bronchial mucous membrane was destroyed by the actual cautery. The pleural cavity devoid of lung was packed with vaselined gauze. The patient withstood this procedure very well.

The progress after operation was smooth and uneventful. Cough and expectoration became insignificant. The patient was able to discontinue the use of a sputum box which had been a necessity for years. On the twelfth day after operation she was allowed out of bed; the temperature, pulse, and respiration were then normal. There was a small amount of drainage from the pleural cavity, which was rapidly obliterated by a further rise of the diaphragm, by an extreme shifting of the mediastinum to the right, and by the falling in of the soft parts of the chest wall in the operative field.

Following the third stage of the operation the amount of sputum was reduced to 60 gm. daily. After the definitive operation there were many days during which there was no sputum, and there was never more than 5 gm. daily. She was allowed to go home on Dec. 15, 1932. Three months later the wound in the chest wall was completely healed except for the opening of a bronchial fistula the size of a pinhead. The fistula is about one and one-half inches in length and leads to the trachea by way of two separate tracts. During the past six months the fistula has closed several times only to reopen again. Eventually thoracoplasty may be required to close it permanently.

During the past eighteen months the patient has been able to lead a normal life at home and has been able to play with other children. Since September, 1933, she has been attending school for the first time in her life. Cough and expectoration are insignificant, and are due entirely to the presence of the bronchial fistula. Moderate dyspnea develops only after considerable exertion.

The author is greatly indebted to the late Dr. Harry Lee Barnes who referred the patient for operation, to Dr. Howard Lilienthal for many helpful suggestions, to Dr. Isaac Gerber who interpreted the x-ray pictures, and to Dr. Meyer Saklad who skillfully managed the anesthesia problems.

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REPORT OF THE CHEST TUMOR REGISTRY*

WILLIAM DEWITT ANDRUS, M.D.
NEW YORK, N. Y.

THE Chest Tumor Registry contains records of 155 cases at present. As will be noted from the following analysis, these cover a wide variety of tumors and have been submitted from twenty-eight clinics. In addition, x-ray pictures of twenty-two cases, photographs in connection with sixteen cases, microscopic sections of thirty-six, and tissue from three are included in the Registry files. For the most part the greatest contributions in numbers have come from men with the greatest amount of material at their disposal, and the Association should be very grateful to these men for the large amount of work entailed in the registration of material.

One hundred and seventeen cases are included in the following analysis, as they constitute those in which the diagnosis may be considered as definitely established through biopsy, autopsy, or operative removal of the tumor. The remaining thirty-eight cases comprise those in which the diagnosis is unproved, and in addition a few instances of metastatic tumors.

PRIMARY CARCINOMA OF THE LUNG

The Registry contains records of sixty-four cases in which the diagnosis of primary carcinoma of the lung may be considered as established. Forty-nine, or 76.6 per cent, of these patients were males, while fifteen, or 23.4 per cent, were females—a ratio of about three to one, a slightly higher incidence in females than that in most series reported in the literature. The youngest patient was a boy of fourteen and the oldest a man of seventy-five. When arranged by decades we find one case under twenty, two between twenty and thirty, and seven between thirty and forty. Thus only 15.5 per cent of the patients were under forty years. The incidence between forty and sixty was much higher, 74 per cent of the patients falling into this age group.

A survey of the occupations of these patients yields nothing which might in any way be considered as of etiologic significance. Eighty per cent did inside work or desk work, while 20 per cent worked out of doors; of the latter there was one stonecutter, four were "laborers," three were farmers, one a gardener, and one a bricklayer.

*Presented in abstract at the Seventeenth Annual Meeting of the American Association for Thoracic Surgery at Boston, Massachusetts, May 31, June 1, 2, 1934.

Pain, cough, and dyspnea constituted most of the presenting symptoms, one or another being the chief complaint in 84 per cent of the cases. Analysis of the symptoms after admission showed cough in 90 per cent, pain in 72 per cent, expectoration in 66 per cent, loss of weight in 60 per cent, weakness in 56 per cent, and dyspnea in 49 per cent. Fever was present on admission in 30 per cent, and 20 per cent showed definite cyanosis.

Closer examination of the symptoms fails to reveal anything which might be considered as characteristic of the disease. Pain was either poorly localized or of a pleural nature and in fourteen cases was referred to the shoulder, arm, back, hip, or nipple. Dyspnea was found both in cases with massive effusion and in cases with pressure on the bronchi, but was also seen in other cases. A rather peculiar feature of this series was the fact that bloody sputum was commented upon in but seven instances. The loss of weight in these patients was very considerable, averaging 25 pounds in the thirty-eight patients in whom it was a prominent symptom.

Previous diagnoses other than cancer of the lung were of interest, nine cases having been diagnosed as pleurisy, nine as pulmonary tuberculosis, seven as bronchiectasis or lung abscess, four as bronchitis, three as pleural effusion, and one each as atelectasis, influenza, fibrosis of the lung, asthma, echinococcus cyst, arthritis, and gallbladder disease.

In considering the physical signs, particularly bearing in mind the possibility of diagnoses of cases which by virtue of the type, location or extent of the tumor, might be candidates for surgery, we find that except in the far advanced cases the physical examination of the chest yielded little of diagnostic significance, and then the signs were those of secondary changes, such as fluid in the pleura or thickened pleura produced by extension of the disease. Evidence of tracheal compression was found in six cases, and signs of vascular compression, in either dilated superficial veins or a difference in blood pressure in the two arms, were commented upon in eleven cases.

Definite evidence of pathologic condition was gained from x-ray examination in fifty-eight of the patients. In nine there was complete opacity of a hemothorax with or without mediastinal displacement, while in sixteen more diffuse dense shadows were seen. Indefinite shadows are reported in five cases, and fibrosis and calcification were each diagnosed in three instances. Seven patients showed hilar thickening, five had mottling of a portion of the lung fields, and in two only hazy outlines of infiltration could be made out.

Most interesting from the standpoint of operative intervention are the eight cases in which a well-defined tumor mass was reported as present in the x-ray picture and the six in which a diagnosis of atelectasis was made, for it seems probable that the cases most likely to present favorable opportunities for surgery will be those discovered early either

through bronchoscopy or through typical x-ray findings of localized tumor without too extensive hilar involvement, or those which produce bronchial obstruction and atelectasis before a diffuse infiltration of the lung and mediastinum has taken place.

Bronchoscopy was performed in twenty of these cases, being negative in three and the mucosa being found to be edematous in three cases. In the remaining fourteen cases tissue removed by means of the bronchoscope proved to be carcinomatous.

Thoracentesis with the withdrawal of fluid was reported in twenty-four of these cases, the fluid being "negative" in nine instances and showing blood in twelve, tumor cells in ten, and echinococcus in one. Tumor cells were found without red blood cells in the pleural fluid of two patients.

Some sort of operative procedure was undertaken in twenty-six cases. Exploratory thoracotomy was performed in thirteen instances, in three of which an attempt was made to extirpate the tumor but without success. In six cases cautery pneumectomy was attempted.

In four of the cases an entire lung was removed. In three of these a posterior approach was used, while in one the approach was anterior. In two instances the bronchus and vessels were ligated separately, and in two a tourniquet was used with subsequent suture of vessels and bronchi. In one case the bronchial lumen was cauterized and radon seeds were implanted. Moderate to extensive adhesions were commented upon in three of the four cases. Preliminary pneumothorax was employed in one case, and in one it was used after operation to relieve negative pressure with dislocation of the mediastinum toward the operated side. Thoracoplasty was employed to obliterate the space left by removal of the lung in two instances. In one of these cases and in another not subjected to thoracoplasty, the phrenic nerve was crushed to permit the diaphragm to aid in obliterating the cavity.

One patient died seven weeks after operation with extensive metastases; one, a recent case, was well six weeks after operation, one was well after seven months and one after two years.

In three cases, lobectomy was performed, the right lower lobe being removed in two instances and the right lower and middle lobes in one. Pneumothorax and phrenic emphraxis were employed as preliminary procedures in one case. In two cases the vessels and bronchial stumps were ligated separately with subsequent reenforcement with pulmonary or mediastinal tissue, while in one the bronchial stump was drained by means of a tube in its lumen.

Of the lobectomy cases, one patient died on the third day with bronchopneumonia, one was well three years later, and one developed recurrences in the bronchial stump two and a half years after operation and at the time of the last report was being treated with radium.

A review of the data on these cases certainly emphasizes the need for earlier diagnosis. How this can be accomplished remains a great problem, but the freer use of bronchoscopy would certainly seem indicated and particularly in cases with atelectasis, as well as the employment of exploratory thoracotomy in cases with more peripheral x-ray findings. When carcinoma of the lung has spread widely enough to enable a positive diagnosis to be made by thoracentesis, it is already beyond the operative stage.

SARCOMA OF THE CHEST WALL

While the predominating form of sarcoma of the chest wall reported in the literature is the chondro- or myxochondrosarcoma, only four of the sixteen cases of malignant tumors arising in the chest wall included in the Registry fall into this group. Of the remainder, ten were fibro- or osteogenic sarcomas, one was a very cellular tumor arising in the right axilla loosely attached to the ribs and composed of small polyhedral cells with many mitotic figures. In another case the diagnosis of sarcoma rests on the x-ray picture of a destructive lesion involving the third, fourth, fifth, and sixth ribs with evidence of pulmonary metastases.

The patients with osteogenic or fibrosarcomas could not well be divided into age groups, as two were 12 and one each 18, 20, 23, 29, 35, 38, 45, and 60 years of age. Six were males and four females. Pain was prominent as a first symptom in five of the ten, but the noting of a tumor was the presenting symptom in all but one of the cases in which it was external. One patient with an osteogenic sarcoma of the eleventh rib near the spine sought medical attention because of paraplegia, and another with pulmonary metastases complained of cough and bloody expectoration before an external tumor appeared. Dyspnea was the chief complaint of one patient in whom a tumor of considerable size and arising from the periosteum was entirely intrathoracic.

In the four chondrosarcomas the presence of a tumor was the presenting symptom in two, while of the remaining two patients in whom the tumor was located in the superior mediastinum, one complained of cough of one year's duration, while the other had been troubled by pain in the arm and by cough and hoarseness for several months.

Previous trauma at the tumor site is noted in the history of but two of the sixteen cases, in one of which it seems likely that this merely served to call the patient's attention to a preexisting tumor. In the other the rôle of the trauma as a true etiologic factor is open to question inasmuch as it occurred only a few days before a definite though relatively limited central osteogenic sarcoma of the rib was removed.

Except in the patients with pulmonary metastases or in which there was a mediastinal mass of very considerable size, loss of weight or weakness was not sufficiently marked to cause comment.

X-ray examination of the chest was particularly valuable in showing any protrusion of the tumor within the thorax and in demonstrating both the portions of the bony thorax involved and the presence or absence of pulmonary metastases. Osteogenesis or osteolysis was demonstrated when present, but, as might be expected, the roentgenograms failed, in some instances, to delimit the actual extensiveness of the lesion in the chest wall, diaphragm or abdomen.

In four of the cases no operation was performed; in two because of obvious pulmonary metastases and in two because of gross destruction of the vertebrae. Twelve of the sixteen were subjected to operation, and in all but one of these an attempt at complete extirpation was made. The excised tumors varied in size from $4 \times 1.5 \times 0.8$ cm. up to one $18 \times 14 \times 9$ cm. The largest successfully excised without recurrence for five years measured $12 \times 10 \times 8.5$ cm. and was a fibrosarcoma composed of relatively well-differentiated cells. In one case the tumor was explored and found to be cystic, being filled with bloody material. The cyst was packed and biopsy taken from its wall.

The methods of extirpation varied somewhat with the tumor and its location. Thus in three cases it consisted in resection of the involved ribs together with the contiguous soft parts and pleura. In two instances it was necessary to resect a portion of the diaphragm in addition to the above. The resection of the tumor alone, separating it by blunt dissection from the underlying rib to which it was loosely attached, proved sufficient in one case, while excision en bloc in another case of sarcoma of the soft parts failed to cure the condition.

The most extensive procedures were employed in the four cases of chondro- or chondromyxosarcoma. In one of these a portion of five of the right lower ribs and costal cartilages with the adjacent soft parts, together with the musculature and peritoneum of the right upper abdomen and a margin of about one centimeter of the liver were removed with the tumor. To close this defect the diaphragm was sutured at a higher level to exclude the pleural cavity and the remainder of the defect closed with skin and muscle flaps. In another case a tumor $8 \times 5 \times 5$ cm. arising from the interosseous tissue of the heads of the upper ribs was removed extrapleurally after anterior mediastinotomy by resection of the second to the fourth costal cartilages and adjacent rib ends. In a third, the tumor in the superior mediastinum, extending into the right lung field, was approached from behind by resection of a portion of the fifth and sections of the third, fourth and sixth ribs. A large tumor was removed in two or three pieces except for a portion of its bed which was attached to the vertebral column and great vessels. A small opening in the pleura was apparently without consequence. The tumor recurred about eighteen months later and gave evidence of its increased malignancy by destroying portions of the second, third and fourth ribs, and the patient died with clinical evidence of brain metastasis about three weeks after a second operation.

In the last case, a large myxochondrosarcoma of the sternum was removed together with the entire sternum below the manubrium and the greater part of the third to seventh costal cartilages of both sides. One pleural cavity, the right, was opened but without untoward effects. Closure was accomplished by skin and muscle flaps. Despite the large depressed defect the patient had no untoward symptoms after operation. The patient developed local and mediastinal recurrences within one year.

The results of the twelve operations were as follows: one patient died of shock five hours after operation; seven patients recovered from operation but developed local recurrences or metastases in from three months to three and a half years; the remaining four were free from recurrences from one to five years after operation.

LIPOMA OF MEDIASTINUM

Records of three cases of lipoma of the mediastinum have been sent to the Registry, and all have features of great interest. One of these was in the superior mediastinum, extending downward about 4 cm. into the chest from a lipoma beneath the sternocleidomastoid muscle. This patient had complained of dyspnea for six months and dysphagia for a shorter period, both of which symptoms were relieved after the removal of the growth.

The other two cases are of particular interest in indicating the really tremendous size to which such tumors may attain. One weighed 12.43 kg. and one 8.5 kg. The first of these patients, a twenty-four-year-old girl, was having distressing symptoms at the time of her admission. These were: sharp pain in left chest and back, of ten months' duration; hacking cough; severe dyspnea; wheezing inspiration; and cyanosis. Physical examination showed complete absence of normal findings over the entire left chest, and x-ray examination showed the left thorax to be almost completely obliterated by a mass which had dislocated the mediastinum to the right and depressed the left diaphragm. Numerous thoracenteses had been attempted but no fluid was obtained. Biopsy was performed after resection of a segment of the fifth rib, and the diagnosis of myxolipoma made. A further operative procedure was attempted, but the patient died during novocaine infiltration with symptoms suggestive of air embolism or novocaine poisoning. Autopsy revealed the enormous size of the tumor, measuring $25 \times 25 \times 13$ cm., and the presence of complete atelectasis of the left lung, depression of the left diaphragm with dislocation downward of the stomach and liver. Fibrinous pericarditis and atrophy of the heart were also found.

The last patient, a thirty-three-year-old man, had complained of dyspnea for four years. One year previous to the onset of symptoms he had sustained an injury over the left lower ribs in a fall. The point of contusion was tender for two months, and a slight swelling was noted. One year later respiratory embarrassment was noted, and x-ray examination showed a well-defined tumor mass in the left lower lung field.

He was operated upon and as much of the tumor as possible was removed. This was found to be a myxolipoma. A sinus persisted at the site, and the tumor rapidly recurred and came to fill the entire left pleural cavity dislocating the mediastinal structures. The dyspnea increased, and he came to have progressive palpitation, edema, and orthopnea, as well as chills, fever and night sweats, and died. Necropsy demonstrated the mass which could be shelled out of the thorax.

A striking and encouraging feature of certain of these tumors reported in the literature is just this fact, i.e., that even when large, their enucleation, considering their size, would appear to be relatively much more easy of accomplishment than is the case with other and smaller tumors.

INTRATHORACIC GANGLIONEUROMA

One of the two instances of this tumor in the Registry occurred in a five-year-old Italian girl, who had had cough and dyspnea for three years previous to operation. Physical examination revealed dilatation of the veins of the right side of the chest and neck and dullness over both upper lobes, most marked on the right. X-ray examination of the chest showed what was thought to be a mediastinal newgrowth involving the right upper chest, which came to dislocate the esophagus and upper mediastinal structures to the left.

At operation a tumor 3.5 inches in diameter was removed through a posterior approach, several inches of the sixth rib being removed and the third, fourth and fifth cut through, the parietal pleura being reflected from the anterior surface of the tumor. The patient succumbed about six hours after operation. On section the tumor proved to be a typical ganglioneuroma, showing ganglion and capsule cells and reticulum fibers.

The second patient, a fifty-five-year-old man, entered the hospital four and a half months after the onset of attacks of pain in the right upper chest and right shoulder. The pain was sharp and stabbing in character and after the acute attack subsided to a dull ache. The acute attacks came on at intervals after or during hard work. The presence of a tumor was demonstrated in x-ray pictures which showed a mass in the right apex extending down to the second rib anteriorly, of even density and having a smooth contour. The tumor was removed and sections showed fibrous tissue, atypical nerve fibers, and scattered ganglion cells. The patient died the following day, having developed a tension pneumothorax on the operated side and widespread subcutaneous emphysema.

OSTEOMA OF RIBS

Reports of two such tumors have been sent to the Registry. The first patient, a man forty-two years of age, had sustained a fracture of the fifth and sixth ribs near the costochondral junction thirty years

previously which had healed but left a "knot on one of his ribs." This had grown larger until it reached 8 inches in diameter. It was not painful or tender, and except for the mass he was without symptoms referable to it. X-ray examination showed no extension into the chest. At operation the tumor was removed from the ribs, but in freeing it from the fifth interspace the pleura was opened. It was sutured, and did not materially complicate the procedure. The sections showed "simple benign osteoma," and the patient made an uneventful recovery.

The second patient, a Chinaman of twenty-six years, first noticed a tumor the size of a walnut four years previous to the time of his admission, and this had grown more rapidly during the past seven months. There was no history of injury. Examination revealed a mass in the left axilla, long, of hard consistency, and firmly fixed to the deeper structures. The ordinary physical signs were impaired over the entire left lung. X-ray examination showed a large, lobulated, radiopaque mass filling the entire left upper thorax and extending outside the bony cage in the axillary region. At operation the tumor was removed together with segments of the first, second and third ribs, which were surrounded by the growth, as well as a portion of the parietal pleura as large as a man's palm. Although adherent to the lung, it was possible to separate the tumor by cutting the adhesions. The wound was closed with a flap of muscle and skin. More than a year later there was no evidence of recurrence. Microscopic examination of the tumor showed it to be a benign osteoma.

ECHNICOCCUS CYST OF LUNG

A single, but very interesting, case of intrathoracic echinococcus cyst has been sent to the Registry. The patient, a forty-year-old man, sought medical attention because of cough with "pinkish" expectoration of three weeks' duration. Examination revealed a fullness and decreased mobility of the left chest. X-ray examination showed a complete opacity over the left lung field below the fourth rib posteriorly, with a convex upper border. The mediastinum was dislocated to the right. The other finding of significance was an eosinophilia of from 18 to 25 per cent. Thoracotomy was performed, and on opening the chest a large quantity (2,000 c.c.) of slightly yellow turbid material containing numerous cysts was evacuated. Several collapsed cysts and fragments of membrane also were found. The large cyst was cleaned out and the wall sponged with tincture of iodine. Complete removal was impossible because of close attachment to pericardium, diaphragm, and lung. A communication with the lung was found on its mesial aspect.

Microscopic examination of the evacuated material demonstrated hooklets, and one year later an echinococcus cyst of the liver was successfully drained. The patient was well and able to do his work as a laborer five years after the thoracotomy.

SARCOMA OF THE PLEURA

This patient, a man thirty-one years of age, came to the hospital because of pain in the right chest, shoulder and arm, of three months' duration. He also complained of a dry cough. Examination showed a swelling in the right supraclavicular fossa and dilatation of superficial veins on the right side of the chest. There was dullness over the right apex down to the fifth rib anteriorly and to the scapular spine posteriorly. Breath sounds were diminished over this area. X-ray examination showed a homogeneous shadow occupying the upper half of the right lung field, sharply defined.

At operation the pleural cavity was opened and a tumor dissected free from the apex of the lung; intracapsular enucleation of the tumor was followed by excision of the capsule except for a small portion adherent to the great vessels.

Sections of the tumor showed it to be composed of myxomatous and malignant connective tissue elements. The patient subsequently developed an empyema which was drained. Five months later diagnostic pneumothorax revealed what appeared to be pleural metastases, and about the same time involvement of the axillary lymph nodes was noted. Following this he lost ground steadily and died.

SARCOMA OF MEDIASTINUM

The sarcomas of the mediastinum as a group are particularly fatal tumors, and while the lymphosarcomas may be somewhat controlled for a time by means of radiation, the literature contains only a few cases in which other types of sarcomas have been successfully removed.

The Registry contains records of seven cases with diagnosis of sarcoma of the mediastinum, of which three were clearly cases of lymphosarcoma as proved by biopsy and necropsy. In another case the differential diagnosis between lymphosarcoma and Hodgkin's disease was not clearly established despite histologic study of a lymph node. In the fifth case a tumor was removed from the superior posterior mediastinum which on section was found to be sarcomatous. The sixth case was that of a tumor first noted in the posterior mediastinum on x-ray examination, which subsequently metastasized to the chest wall where a nodule was removed and on section showed "sarcoma of undetermined origin." In the seventh case the diagnosis of sarcoma was made on the basis of clinical and x-ray findings, and appears to be somewhat open to question.

One of the cases of lymphosarcoma was remarkable in that during the four months which elapsed after the onset of the first symptoms, dyspnea, and edema of the left arm, something over 39,000 c.c. of fluid was removed from the pleural cavities. The duration of life in the lymphosarcoma patients was three months, four months, and one year.

The patient with possible Hodgkin's disease lived five years after the first lymph node enlargement was noted.

In only one case in this group was operation directed toward the removal of the tumor. In that case a tumor 12×8 cm. was removed from the posterior mediastinum, after resection of 3 inches of the fourth, fifth and sixth ribs and section of the second and third. Because of the firm attachment to the chest wall, its enucleation was very difficult and was accompanied by severe bleeding. It was necessary in this case for the operator to open the pleura widely. The patient died.

MEDIASTINAL HODGKIN'S

Aside from the difficulty, other than by biopsy, of differentiating Hodgkin's disease from lymphosarcoma in the mediastinum, it may occasionally simulate other types of tumor more amenable to surgery. We have included two cases of mediastinal Hodgkin's disease illustrative of this point.

The first of these, in a twenty-four-year-old girl, was associated with an x-ray shadow of a "well-defined, rounded mass in the lower third of the right lung field, apparently springing from the mediastinum." The x-ray diagnosis suggested "a tumefaction arising from the mediastinum, probably cystic in nature." Exploration carried out through resection of the fourth and fifth right costal cartilages showed a fixed mediastinal mass apparently surrounding the vessels and which was unrelieved by decompression.

The second case was diagnosed as lymphosarcoma clinically, as it well might have been, and the patient received x-ray treatments at intervals over four and a half years with transient relief and finally died of cachexia and decubitus ulcers. Autopsy revealed the true nature of the condition as mediastinal Hodgkin's disease which had invaded the lungs, pericardium, and heart muscle, and compressed some of the bronchi.

MYXOMA OF MEDIASTINUM

A single case of this type of tumor is included in the Registry files. The patient, a man of forty-three years, sought medical attention because of a lump in the region of his right breast. Physical examination revealed a mass in this region 4×4 cm. in size, and x-ray examination showed a large dense circular shadow over the mid-section of the right lung field with fairly clear-cut boundaries. Pressure atrophy of the third and fourth ribs anteriorly was also suggested. The physical examination, save for the local findings, was unremarkable except for dilatation of the left pupil.

The operation, begun under local anesthesia with positive pressure N_2O, oxygen later, consisted in section of the pectoralis major near its insertion, retracting it mesially, and section of the pectoralis minor, exposing the tumor protruding between the third and fourth ribs anteriorly

and causing an elevation and pressure atrophy of these ribs. The third and fourth ribs were then resected subperiosteally, and the tumor was freed from its bed by blunt dissection. It was found to extend for a considerable distance beneath the sternum. The pleura was torn in this maneuver, and a portion attached to the tumor was excised. The institution of positive pressure anesthesia at this point successfully obviated any untoward effects, and the pleura was sutured, the sutures being tied after inflation of the lung.

The tumor measured 14×10×10 cm. and on section was found to be composed of myxomatous tissue. The patient made an uneventful recovery and was well and at work four years later.

CARCINOMA OF THE MEDIASTINUM

A case submitted under the above diagnosis was that of a fifty-four-year-old woman who entered the hospital because of chills, fever, and pain in the chest. She had had pain in the chest on both sides and a nonproductive cough for twenty-nine months, and slight dyspnea, worse when prone, for one year. Physical examination revealed a firm nodule protruding from the suprasternal notch, which did not appear to be attached to the thyroid. There was no lymphadenopathy. X-ray studies over two and a half years revealed the increase in size of a mass on the right side of the superior mediastinum, protruding to the right beneath the second and third ribs. Biopsy of the protruding mass revealed carcinoma of giant cell type (thymus) apparently growing rapidly.

CYSTS OF LUNG

We have records of two cases of cysts of the lung. One, apparently congenital, was in a male infant of sixteen months. The child had had evident dyspnea and wheezing respirations since birth. Physical examination revealed very poor nutrition, dilatation of the veins of the neck and an audible stridor. X-ray examination showed increased density of the left side with cardiac displacement toward the left and what appeared to be "hyper-aeration" of the right lung field. The child died, apparently of pneumonia, and at autopsy the right middle lobe was found to be completely occupied by a thin-walled unilocular cyst which measured $9 \times 6.5 \times 4.5$ cm.

The second patient, a woman of fifty-four years, complained of pain in the chest and occasional dyspnea. Physical and x-ray examination revealed a large mass in the upper left chest extending to the ninth rib posteriorly and dislocating the heart to the right for a distance of about 3 cm. Puncture of this mass yielded serosanguineous fluid. The cyst was drained on several occasions during the last five years of her life and finally a permanent fistula was made. Four and a half years after the first operation and two months after the last the patient died of pneumonia, having also developed a severe hypertension.

ENDOTHELIOMA OF PLEURA

The exact origin of these uniformly fatal tumors is still the subject of speculation, yet the clinical and pathologic characteristics are such as to justify their inclusion as a special group. Four carefully studied cases are to be found in the Registry files under this diagnosis. All were males, being 34, 50, 61 and 70 years of age, and all died in from six to eighteen months after the onset of symptoms.

The most constant and prominent symptom in all was pain in the chest, sharp or severe in nature, and present in these cases for from four to eighteen months. Three of the four also complained of cough with mucoid, mucopurulent or blood-tinged sputum. Loss of weight of twenty to thirty pounds and progressive weakness is commented upon in three of the cases. Dyspnea becoming very marked as the disease progressed was also a prominent feature in three instances.

Clinical examination uniformly revealed decreased mobility, decreased fremitus, dullness, and absent or markedly diminished breath sounds over one entire side of the chest. A striking feature of one case was the presence of unilateral exophthalmos on the same side as the chest lesion. X-ray examination eventually suggested the presence of massive effusion in all cases, although in one case a shadow suggestive of tumor was seen over the apex of the lung.

Thoracentesis yielded amber fluid in one case and bloody in another, and in both of these large tumor cells were found in the sediment.

Exploration of the chest was performed in the other cases. Bloody fluid overlying the involved pleura was found in one patient, while in the other a nodule was found eroding a rib, and a portion of this was removed for biopsy.

Postmortem examination in three of the cases showed the lung collapsed in a pleural cavity containing a large quantity of serosanguineous fluid. The visceral pleurae were found thickened and more or less covered with flat nodules. Microscopic studies revealed these to be composed of large cells with fairly clear cytoplasm and large hyperchromatic nuclei.

SARCOMA OF THE LUNG

Of this type of tumor, springing from the supportive tissue of the lungs or pleura, four cases are included in the Registry, two in males and two in females. Their ages were 35, 48, 51, and 54 years respectively. Two patients sought medical care because of pain in the chest and two came because of cough, in one hacking and nonproductive, while in the other, in whom the growth involved the lining of a bronchus, it was associated with persistent hemoptysis. Dyspnea was a prominent symptom in two patients, and two complained also of marked weakness and loss of weight. Physical signs gave evidence of replacement of

lung tissue by a mass or fluid in all cases, and the most important information was obtained by the laboratory examinations.

In one case the x-ray examination indicated the presence of massive pleural effusion. This patient was subjected to exploratory thoracotomy, and a large, beefy mass was encountered which involved the lung, and sections from which showed fibrosarcoma. In another a mass was demonstrated by x-ray examination springing out from the mediastinum, suggestive of malignancy, and the presence of numerous small cavities at the apex. Pneumothorax was induced causing a partial collapse, and this was completed by means of thoracoplasty. This was followed by marked improvement—so marked, in fact, that the previous diagnosis of malignancy was questioned. Despite the quite adequate collapse, however, hemoptysis continued and within six months became alarming. Bronchoscopy was then employed and revealed a growth in the left secondary bronchus, section of which showed a very vascular sarcoma.

X-ray examination in the third case also suggested the presence of fluid, but none could be obtained on several taps, and autopsy revealed an obliteration of the pleural cavity due to adhesions overlying a voluminous lung honeycombed with bronchiectatic cavities. This was associated with a peribronchial spindle cell sarcoma involving the major bronchi and spreading out along the finer branches, markedly narrowing their lumens.

In the fourth case a large opaque mass was visible in the left lung field surrounded by "a clear space." Thoracotomy revealed a large grapefruit-sized mass springing from the mesial edge of the left lower lobe and adherent to the pericardium. This was removed together with a portion of the lobe and except for a bronchial fistula, the patient made a complete recovery from the operation. The tumor proved to be a fibrosarcoma.

DERMOID CYST OF MEDIASTINUM

Records of seven cases of mediastinal dermoids are included in the Registry, three in males and four in females. The patients' ages were 23, 28, 30, 33, 39, 43, and 55 years respectively. Pain in the chest varying in character from acute stabbing attacks to a feeling of soreness was the most constant, and the most prolonged symptom, having been noted as the chief complaint in five of the seven cases. Dyspnea, accentuated by exertion and in one instance at least by change of position, was the next most common symptom. A survey of the records indicates that this symptom depends, as we might expect, both upon the size and upon the location of the tumor. One patient, for example, in whom the tumor was quite small (2.5 cm. in diameter) was free from dyspnea except when lying on her back. Cough was noted as a prominent symptom in five of the cases, but in only one was the sputum of aid in establishing the diagnosis. This patient, the same one men-

tioned above who suffered from dyspnea when lying on her back, expectorated blood-tinged mucopurulent sputum in which cheeselike particles and hairs were found from time to time.

The symptoms referable to the presence of the cysts had been present for intervals varying from six months to eleven years in the different cases.

The x-ray examination was the most useful diagnostic method, showing a rounded mass of uniform density and with a clearly defined edge in practically all of the cases.

These seven patients were all subjected to operation, and in three of them the tumor was completely excised in one stage. One of these patients died about twenty-four hours after operation with signs of mediastinal emphysema, but the remaining two were living and well six months and seventeen months after operation. The tumors were approached by different routes. One in the anterior mediastinum on the left was exposed by means of an incision through the sternum carried into the first and sixth interspaces with retraction of the ribs and left border of the sternum as a trapdoor. The other, in the lower right mediastinum, was attacked and completely removed by means of a transpleural approach through a long incision with resection of the eighth and ninth ribs.

In one case the tumor, a true teratoma of the anterior mediastinum, was removed in multiple stages over a period of months and after resection of a portion of the sternum and adjacent costal cartilages. The patient recovered and has been well for about eight years.

Drainage of infected cysts was employed in two instances, and in both of these the larger portion of the wall subsequently sloughed away so that one of the patients was completely cured while another still had a small draining sinus. Another case, multilocular, was drained after multiple attempts to search out the various pockets, and was greatly improved but still had a persistent bronchial fistula eight years after operation.

To summarize: Of these seven patients, one died after excision; two were cured by one-stage excision, one by excision in multiple stages, and one by marsupialization. One patient was much improved but had a persistent bronchial fistula.

From an analysis of the material in the files, it is evident that for the better development of the Registry, and if it is to be representative of the collective experience of the Association, it is necessary not only that more cases should be reported, but also that each should be accompanied by all available data including x-ray prints, photographs if possible, and in any event microscopic sections or microphotographs of the tumor tissue. The burden of submitting the data can be somewhat lessened if only those cases are submitted in which the diagnosis has been definitely established by microscopic examination of tissue removed.

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PLEURAL POUDRAGE

A New Technic for the Deliberate Production of Pleural Adhesions as a Preliminary to Lobectomy*

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SAMUEL ROBINSON said, in 1917, in a discussion on resection of the lung,[1] "If one lobe can be anchored so that it remains in position during resection of the other lobe or lobes, the chief obstacle to successful lobectomy will be removed." No uniformly successful method to this end has, so far, been discovered. The methods employed for either local or generalized pleural symphysis might be listed as follows:

A. Extrapleural

1. Packing tampons of gauze against the exposed parietal pleura, usually after the resection of ribs, periosteum and intercostal muscle.

2. Packing against the exposed pleura—with or without the removal of ribs—rubber bags, rubber sponges, sea sponges, silk.[2, 10]

3. Same as above, using a paraffin plombe[2] (Sauerbruch, 1924).

4. Chemical irritation of the exposed parietal pleura with tincture of iodine, Lugol's solution, silver nitrate, formalin, carbolic acid, zinc chloride paste, turpentine in olive oil, eucalyptus oil.[8, 10]

5. Stitching the lung to the parietal pleura, without opening the chest.

6. Mechanical irritation of the exposed parietal pleura by curettage.

7. Thermo-electrical irritation of the exposed parietal pleura.

B. Intrapleural

8. Injection into the pleural space of an irritating chemical, such as tincture of iodine, ether, alcohol, formaldehyde, gomenol, silver nitrate, sudan III, 50 per cent dextrose saline, glycerin, gum arabic, turpentine.[3, 4, 10]

9. Exposing the visceral pleura and wiping with gauze.[5]

10. Scarifying the visceral pleural with a needle.[4]

11. Stitching the lung and visceral pleura to the parietal pleura.

12. Introduction of elastic bands.[3]

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13. Introduction of silver wire.[3]

14. Tamponing open pleural space with gauze.[1, 6, 7, 8]

15. Enclosing lung in silk bag tied about the hilus.[9]

16. Introduction of half-inch tape between the two pleurae (Bettman[3]).

17. Same under thoracoscopic control (Bethune).

18. Cauterization of the parietal pleura under thoracoscopic control (Bethune).

19. Introduction of irritating gases, such as chlorine and bromine, into the pleural space (Bethune).

20. Introduction of aerial suspension of solid particles (magnesium oxide) and carbon (smoke) (Bethune).

21. Dusting on the visceral or parietal pleura or both, talc powder, under thoracoscopic control (Bethune).

COMMENTS ON METHODS

Methods 1, 2, 4, and 5 have been used clinically by us only for strictly limited and localized adhesion production over lung abscesses. Methods 8, 16, 18, 19, and 20 have been employed experimentally and not clinically. Method 17 (modification of Bettman's) has been used both experimentally and clinically. Method 21 is the one to be described in detail. It has been used clinically by us four times in the past year, after experimental work.

We early abandoned (1929) the methods of injecting into the pleural space irritating chemicals. After trying a large variety of solutions, we came to the same conclusion as Alexander,[4] that they were useless, uncertain, or dangerous. Adhesions, if any, are produced in undesirable locations, such as the base. Method 18 (1930) was used in dogs. It seemed a painful one to the subject. The adhesions produced were flimsy. The common complication was fluid formation. Its most serious objection was that the adhesions were confined to the injured area, which on account of the technical difficulties involved was of limited extent. When working on the problem of producing localized pneumothorax in tuberculosis (1928) (this work has been abandoned), Method 16 (Bettman's) was used experimentally on four dogs. We agree with its originator that firm adhesions are produced. It was found if half-inch tape was threaded through an intercostal space and pulled out through another opening, that, where the lung lay against the tape, a very dense tunnel of adhesions was formed. These adhesions are of necessity linear and are confined to the immediate neighborhood of the tape. (Fig. 1.) Intimate contact of the lung with the tape is essential. Tape should be removed within seven days, or an empyema will result. This method, although interesting, would appear to have limited clinical applicability. We have used it once

clinically as a preliminary to lobectomy. (Fig. 1.) Method 19 (1930) failed to produce adhesions in cats. Chlorine gas (1:2,000), and bromine gas (1:5,000) were used. Method 20 (1931) was the use of magnesium oxide vapor made by igniting photographers' flare-ribbon. After the white gas was collected in a small pneumothorax apparatus, it was injected into the pleural space of cats. It failed to produce adhesions. Carbon particles, as smoke, were also injected in the same way. They sometimes produced widespread, patchy, filmy adhesions. We felt we were approaching the ideal in Methods 19 and 20.

1. A selective upper lobe pleural irritant, to be applied in a pneumothorax space without great technical difficulty and without opening the chest.

2. Penetration of the irritant (and of necessity it must be an irritant) into the crevasses of the pleural cavity.

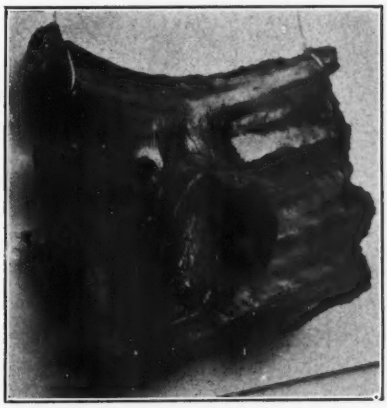

Fig. 1.—Pleural adhesions, two weeks, in dog. Bettman's method.

3. Nondependence on special posture to retain the irritant over any selected pleural area.

4. Nonabsorbability of the irritant to prevent harm to the body generally.

5. A short, self-limiting pleural reaction to be set up, if possible, without fluid formation and which would rapidly subside, leaving the adhesions as harmless sequelae.

Method 21 was a logical outcome of the former experiments. A number of fine powders were blown in through cannulas onto the collapsed lung, the spinal gutter, and the mediastinal surface of dogs and cats already subjected to a unilateral pneumothorax. Boracic acid powder was first used. It was noneffective. Various medicated dusting powders were then tried. Most of them were found to be too irritating to dogs. The pulmonary fibrosis produced in silicosis was

then brought to mind. A silicate powder appeared to possess obvious advantages. The actual silicate powder selected (commercial talc) was suggested by the late Dr. R. U. Harwood of the Royal Victoria Hospital. It is an insoluble compound of magnesium and calcium silicates. This talc powder was experimented with in the following way. In six dogs and six cats a pneumothorax was induced. Incidentally, two of the dogs showed that a bilateral pneumothorax had been inadvertently produced. Through a sixteen-gauge needle, 0.5 c.c. of sterile talc powder was blown in on the collapsed lung. The pneumothorax was immediately withdrawn to get the two pleural surfaces in contact. The total extraction of air was not always successful, especially in the

Fig. 2. Fig. 3.

Fig. 2.—Pleural adhesions, two weeks, in cat. Talc powdered over upper right lung. Note adherent right upper lobe. All other lobes free.

Fig. 3.—Pleural adhesions, one month, in dog. Talc powdered over right lung. Firm adhesions between upper lobe and mediastinum.

dogs. Much to our surprise, no pleural effusion resulted in any of the experimental animals. X-ray pictures were taken every twenty-four hours for the first week, and afterward once a week. The animals were sacrificed at weekly intervals, up to two months. In two of the cats the pneumothorax was not extracted. They were sacrificed at six weeks. They showed little or no adhesions, in spite of the presence of large collections of talc nodules over the visceral pleura. All the animals in which the x-ray pictures showed that there had been complete extraction of air of the pneumothorax after the injection of the talc, showed widely scattered firm adhesions, without

preliminary fluid formation. The extent of the adhesions varied. Some had the surface of one lobe (most often the upper lobe) completely fixed to the chest wall. In others only a part of the lobe would be fixed. (Figs. 2 and 3.)

The pleura at autopsy after the first week was not inflamed. It appeared normal except for interpleural adhesions, at the base of which were small white hillocks of talc powder on the surface of the lung. The parietal pleura also contained in some cases collections of talc at the base of the costal end of the adhesions. Most of the collections of talc were about the size of pinheads. Some of these collections had no adhesions running over to the chest wall. Here, it was felt, the

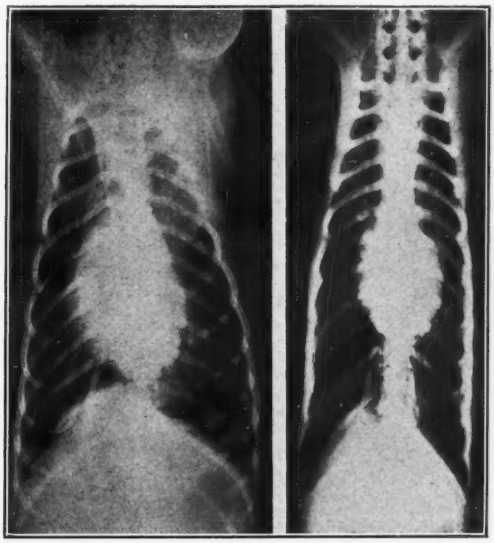

Fig. 4. Fig. 5.

Fig. 4.—Dog, twenty-four hours after pleural poudrage with talc. No fluid.
Fig. 5.—Cat, six weeks after pleural poudrage with talc. No fluid.

two pleura had not been in intimate contact immediately after the operation, owing to the incomplete aspiration of the pneumothorax. The adhesions were moderately firm after one week, but after a month were so strong as to resist digital separation.

REPORT ON EXPERIMENTAL SECTIONS

Cat 761, three weeks. There are a number of large and small nodules scattered over the visceral pleural surface. No nodules are seen in the lung itself. These nodules are well localized, and the pleural surface between them is relatively normal and unthickened. The nodule is completely surrounded by a fibrous tissue, but on its outer surface it is much thicker and appears to be a direct continuation of the pleura itself. Between the nodule and the parenchyma of the lung there is only a

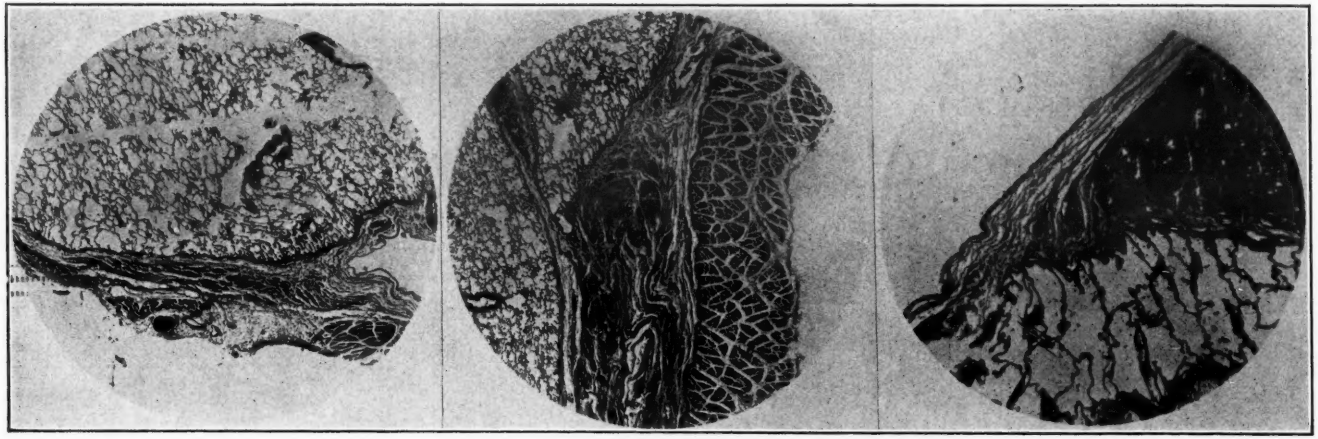

Fig. 6. Fig. 7. Fig. 8.

Fig. 6.—Cat 761, three weeks after pleural poudrage with talc. Thick adhesions between two pleural surfaces. Note normal lung parenchyma above, intercostal muscles below. (Low power.)

Fig. 7.—Cat 770, eight weeks after pleural poudrage with talc. Dense pleuropericardial adhesions, also interlobar adhesions. Both cardiac muscle and lung parenchyma are normal.

Fig. 8.—Dog 3, six weeks after pleural poudrage with talc. Edge of talc nodule with no interpleural adhesions.

relatively thin fibrous membrane. The nodule consists of a predominance of fibroblasts, in the meshes of which are talc crystals. In addition one sees, occasionally, plasma cells and polyhedral macrophages, also larger cells simulating reticulocytes. No polymorphonuclear cells are seen. Giant cell formation has not occurred. The parenchyma of the lung is normal. In other sections, in addition to the nodular thickening, a diffuse thickening has occurred on the pleural surface. This is principally fibroblastic, and from it dense strands composed of bundles of fibroblastic cells extend over to the parietal pleura as adhesions. In these strands, talc crystals are occasionally seen. Here the reaction is much less cellular, and more fibrous than in the independently demarcated nodules. The parenchyma is free. The nodules are comparatively avascular.

Dog 3, six weeks. The nodule consists of an outer zone of fibrous tissue similar to that seen in Cat 761, and beneath this is a thick layer of mature hyaline fibrous tissue. Immediately beneath this is a large deposit of talc. Beneath and between it and the parenchyma of the lung, is a more cellular zone, containing numerous crystals surrounded by fibroblasts, and large polyhedral reticulocytes, and an occasional plasma cell. There is a fine zone of fibrous tissue, separating the nodule from the parenchyma. It would appear that the pleura rose over the nodule as a direct continuation. The talc crystals seem to be in the deep layers of the pleura, and the main structure of that membrane swings over the top of the nodule.

Cat 770, two months. Section of adhesions between the pericardium and the lung. Where the pleura and pericardium are fused together, the endothelial layers of each seem to have disappeared, and direct continuation of one to the other has occurred. There are dense fibrous strands of adhesions containing talc. Both the heart muscle and the lung are normal in appearance and contain no talc. The tracheobronchial lymph nodes at the hilus contain no talc, and appear free of reaction.

COMMENT

In spite of the more or less uniform scattering of the talc at operation, at postmortem the powder is seen to be heaped up in well-demarcated nodules. This observation combined with the appearance of the talc crystals as being in, and not on, the pleura would suggest that the crystals have been picked up by the pleural lymphatics, and carried along until their total mass blocked the lymph channel, resulting in the nodule.

CLINICAL APPLICATION OF EXPERIMENTAL METHODS AS PRELIMINARY TO LOBECTOMIES

Half-inch tape is applied through a small cannula, guided with forceps over the surface of the partially collapsed upper lobe, under thoracoscopic guidance, in a closed pneumothorax.

Case 1.—Mrs. A. D., aged twenty-nine years, No. 48409, Royal Victoria Hospital. Diagnosis: left lower lobe bronchiectasis. Left artificial pneumothorax two months. Sixty per cent collapse of upper lobe, 40 per cent of the lower lobe. Adhesions between the lower lobe and the diaphragm, and the lateral costal wall. Upper lobe free of adhesions. April 19, 1933, inspective thoracoscopy. Under local anesthesia thoracoscope introduced in seventh space scapular line. Demarcation between the diseased lower lobe and the healthy upper lobe clearly observed. Upper lobe entirely free from adhesions. Two small cannulas inserted, one in the fifth space, anterior axillary line, and the other in the fourth space posterior. Thoracoscopic

forceps introduced through the axillary cannula grasped the end of a length of half-inch tape pushed through the upper cannula. Pulled through 12 inches and spread it out in a criss-cross fashion over the surface of the upper lobe just above the great oblique fissure which could be easily seen. Cut off the upper end of the tape and after pulling out the cannula, buried the end of the tape below the skin. Extracted the pneumothorax immediately. April 24, pulled tape out and aspirated 600 c.c. of clear sterile fluid. May 5, one-stage lobectomy (Archibald). Posterior to the midaxillary line the upper lobe was held out by firm adhesions. Anterior to this there were none. During operation the upper lobe collapsed 50 per cent. No fresh adhesions over the lower lobe.

COMMENT

When the tape is spread out over the collapsed upper lobe in this fashion, as the lung expands when the pneumothorax is extracted, the tape covering the collapsed lobe is rotated backward and outward, and a large part of the anterior surface of the lobe is uncovered by it. As a result, no adhesions are produced in this area. If, instead of the lower end of the tape being left free on the lung, as it was, it had been pulled out through the lower cannula, we might have expected that more adhesions would be produced, but with the objection that they would have been linear only and any breakdown of this line during operation would have resulted in complete collapse of the upper lobe. The zigzag method of applying the loose end of the tape at least produced adhesions over a wide area of this lobe.

Pleural Poudrage.—The production of selective pleural symphysis by the injection of talc powder with a powder blower, under thoracoscopic guidance, onto the surface of a partially collapsed upper lobe, in a closed pneumothorax.

CASE 2.—J. L., aged thirty-two years, No. 14240, Sacre Coeur Hospital. Diagnosis: bilateral basal bronchiectasis. May 10, 1933, left artificial pneumothorax. Upper lobe entirely free of adhesions and 80 per cent collapsed. Thick adhesions of diaphragm to lower lobe. Small amount of fluid in the sulcus. June 7, pleural poudrage. Two drams of talc blown in over the upper lobe under thoracoscopic vision. Local anesthesia. Immediate extraction of pneumothorax. Operating time, fifteen minutes. Temperature rose to 101.8° F., pulse 120, in forty-eight hours, but both returned to normal in five days. No more fluid than originally seen. No postoperative pleural pain or discomfort. July 21, one-stage lobectomy (Bethune). Entire symphysis of the visceral and parietal pleurae covering the upper lobe. Lower lobe free of artificial adhesions except just below the oblique fissure. These adhesions were firm, but could be broken down with the finger without bleeding. No fluid. (Figs. 9, 10, 11, and 12.)

CASE 3.—Rev. F. E., aged eighteen years, No. 14917, Sacre Coeur Hospital. Diagnosis: right lower and mid lobe bronchiectasis. June 13, 1933, right pneumothorax. Seventy-five per cent collapse of the upper lobe. No adhesions. Mid and lower lobes partly adherent. No fluid. June 24, pleural poudrage and phrenemphraxis. One dram ½ per cent iodized talc, powdered over the upper lobe under thoracoscopic guidance. Local anesthesia. Immediate extraction of pneumothorax. Temperature rose to 102° in forty-eight hours, pulse 100. Both returned to normal in four days. No pleural fluid formation. No postoperative pain. August 21, at-

tempted pneumothorax. Only 250 c.c. of air with pressure of plus 2 could be introduced. This air collected over the top of the diaphragm. August 28, one-stage lobectomy (Bethune). Complete symphysis of pleurae over the upper lobe. No fluid.

Fig. 9. Fig. 10.

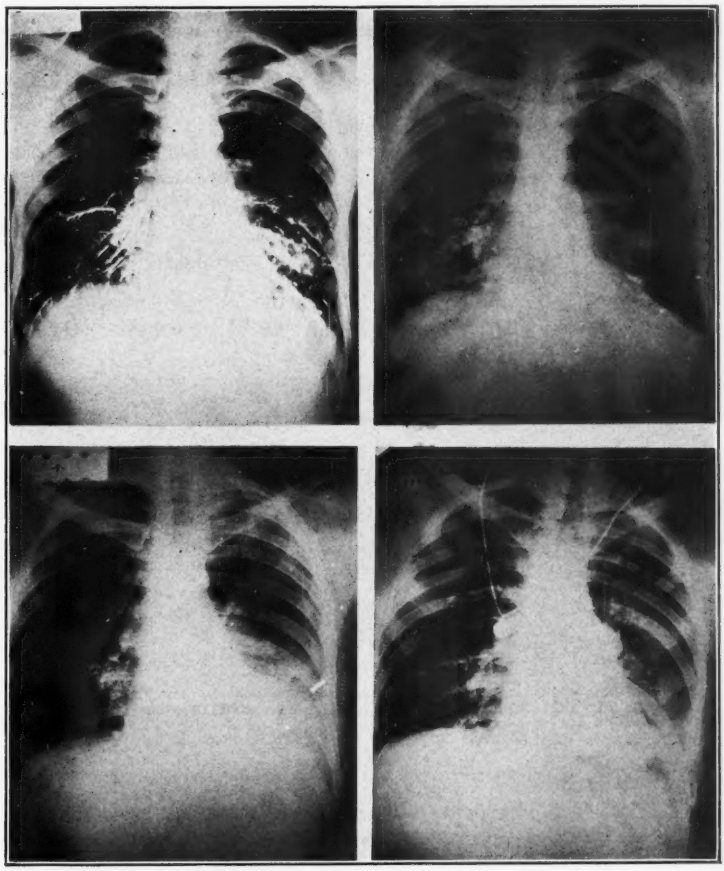

Fig. 11. Fig. 12.

Fig. 9.—J. L., No. 14240, Case 2. Bilateral basal bronchiectasis, predominantly left.

Fig. 10.—Case 2. Left pneumothorax, adhesions of lower lobe to diaphragm. Upper lobe entirely free. Small amount fluid.

Fig. 11.—Case 2. Twenty-four hours after pleural poudrage. Small pneumothorax still remains. No increase fluid.

Fig. 12.—Case 2. Seven days after lobectomy of left lower lobe. Upper lobe fully expanded. Capacity of pleural cavity 75 c.c.

Case 4.—W. P., aged thirty-five years, No. 87823, Royal Victoria Hospital. Diagnosis: right lower lobe bronchiectasis. Artificial pneumothorax two months. No fluid. Seventy per cent collapse of upper lobe. No adhesions. December 13, 1933, pleural poudrage. Two drams ½ per cent iodized talc. Complete extraction of pneumothorax immediately. Temperature 101°, settling to normal in six days. No

fluid formation. Moderate amount of postoperative pain. January 25, 1934, one-stage lobectomy (Archibald). Complete symphysis of pleurae over upper lobe. No fluid.

CASE 5.—Miss P. L., aged fourteen years, No. 15015, Sacre Coeur Hospital. Diagnosis: right lower lobe bronchiectasis. November, 1933, right pneumothorax. Upper lobe free of adhesions and 75 per cent collapsed. Adhesions to lower lobe only. December 4, pleural poudrage and phrenemphraxis. One-half dram of ½ per cent iodized talc, powdered over the upper and mid lobes under thoracoscopic vision. Immediate extraction of pneumothorax. X-ray picture in twenty-four hours showed small apical pneumothorax. Extracted additional 300 c.c. of air. Reaction: 102° temperature in forty-eight hours, settling to normal in five days. No fluid formation. January 15, 1934, attempted pneumothorax; no free space found. January 18, one-stage lobectomy (Bethune). Upper and mid lobes firmly stuck to the chest wall. No fluid.

TECHNIC OF PLEURAL POUDRAGE

Prepare ½ per cent iodized talc, using a fine commercial talc powder. Sterilize in autoclave. Under local anesthetic, insert the

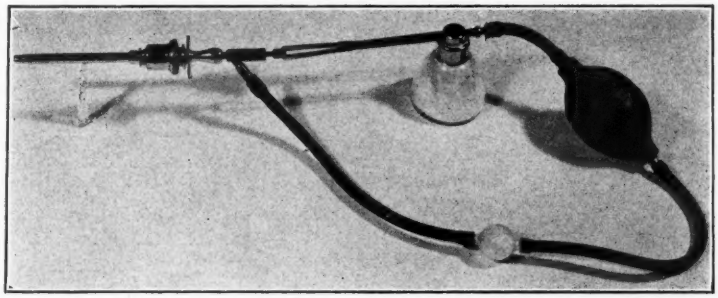

Fig. 13.—The author's return-air pleural powder blower. The cannula is inserted through the air-tight cannula of the Jacobeus-Unverricht thoracoscope and projects just beyond its tip.

thoracoscopic cannula with an air-tight valve in the sixth or seventh space scapular line. Inspect the pleura. Take out the thoracoscope and insert through the same cannula the author's return-air powder blower. Give half a dozen puffs, then insert the thoracoscope again and inspect. Repeat as often as necessary to cover the surface of the upper lobe. If the mediastinum is to be covered, use a slightly longer cannula than the regular one which projects only half a centimeter beyond the tip of the thoracoscopic cannula. Avoid touching the lung with the tip of the cannula as the moisture will clog the end. When the lung is covered so as to resemble a cake sprinkled with confectioners' sugar, detach the blower and completely aspirate the air. To do this it is necessary to use a side opening cannula which is a part of my apparatus. Check up immediately by x-ray examination before the patient returns to the ward, to be sure that all the air is extracted.

If a line of pneumothorax is seen on the film over 0.5 cm. in width, this air must be extracted the same day. If less than this, it may be left.

The advantage of the return-air blower* over an ordinary powder blower is that no more air is admitted to the chest during the operation than that with which one started. In consequence, the pleural pressures remain constant. The air to operate the blower is extracted from the pneumothorax, and is returned to it. The talc was iodized to intensify its action. Perhaps it is unnecessary. (Fig. 13.)

CONCLUSIONS

1. It would appear that a technic has been found which can produce, at will, selective pleural symphysis, without fluid formation, as a preliminary to intrathoracic surgical operations such as lobectomy.

2. The agent employed is iodized talc powder, blown in with a special blower, under thoracoscopic guidance, in a closed pneumothorax.

3. Ten months have passed since the first clinical case was operated on, and up to the present there is no reason to believe that ill effects are to be expected from the presence of this insoluble powder between the two pleural surfaces.

Our sincere thanks are due to Dr. T. R. Waugh for his kindness in reading the experimental sections. The experimental work was done in the laboratories of McGill University, under a grant generously donated by Percy Cowans, Esquire, of Montreal.

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*The powder blower was made by The George P. Pilling and Son Co., Philadelphia.

THE INCIDENCE OF HIATUS HERNIA IN PREGNANT WOMEN AND ITS SIGNIFICANCE*†

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A DEFINITE change in our conception of diaphragmatic hernia occurred following the contributions of Morrison[11] and Healy[7] in 1925 and Åkerlund, Öhnell and Key[1] in 1926. Åkerlund, particularly, pointed out that herniation through the esophageal orifice of the diaphragm, often called paraesophageal hernia, is a relatively common condition, and at least six times as frequent as are all other types of diaphragmatic hernia. He subdivided the hernias through the esophageal hiatus into three groups; it is only with the third that we are here concerned. The first two are relatively uncommon, are generally considered to be congenital in origin, and have aroused little or no controversy as to their character. The third type includes those cases in which a portion of the cardiac end of the stomach protrudes through the esophageal hiatus into the thorax with the esophagus entering into the hernial sac. Thus the abdominal portion of the esophagus lies above the diaphragm and enters the stomach at this point. It is in this group that the large number of small and spontaneously reducible hernias occurs.

Following the above mentioned publications there appeared a number of papers attesting to the frequency of hiatus hernias. Included in these was the paper of Barsony[3] in 1928, a report of nineteen cases by Ude and Rigler[16] in 1929, of sixty cases by Ritvo[13] in 1930, and an even larger number by Moore and Kirklin.[10] Ritvo's report indicated that hernias of varying size occurred in about 0.75 per cent of all cases examined for gastrointestinal complaints. Although this appeared to be a very high incidence, our own experience over a period of five years has indicated an even greater frequency, forty-four cases being diagnosed in about 4,200 roentgen examinations of the stomach.

Many observers have speculated as to the etiology of the third group of hiatus hernias. Most of them have considered that the condition is due to a weakness of the diaphragm at the esophageal hiatus, either congenital or acquired. This may result in a herniation when some exciting cause, such as trauma, increased intraabdominal pressure,

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loss of subdiaphragmatic fat, etc., supervenes. Harrington,[6] for example, considers them to be congenital in origin with much the same mechanism of production as occurs in inguinal hernia. Wagner[18] discusses these theories of causation in considerable detail.

In the report by Ude and Rigler[16] it was noted that the females far outnumbered the males (15 to 4), that the patients were advanced in age, that there was a history of frequent pregnancies in many of the women, and that there were seven cases with intraabdominal tumors or ascites. These data suggested strongly that, at least in the immediate induction of the hernia, increased intraabdominal pressure was a very large factor. We resolved to put this theory to the test by making roentgen examinations of the stomach on women who were in the third trimester of pregnancy. We thought that this would be a simple method of obtaining patients with increased intraabdominal pressure who otherwise were reasonably normal.

These patients were chosen entirely at random and, while many of them had the usual gastrointestinal symptoms of pregnancy, no effort was made either to exclude or to select those with symptoms. The patients were examined fluoroscopically by the usual technic as described by the observers referred to above. In every case examination in the supine, prone, and horizontal oblique positions, as well as the upright was made. There is a notable lack of success in demonstrating these types of diaphragmatic hernia in the upright position because they usually reduce themselves. The only effort which was made to increase the intraabdominal pressure was by means of deep inspiration, cough, or efforts at bearing down. Films were made, usually under the fluoroscopic screen, in all positive and doubtful cases. A strenuous effort was made to distinguish sharply between regurgitation into the esophagus and actual herniation. All cases were observed after complete emptying of the esophagus, but, occasionally, examination of the esophagus with barium paste was resorted to after a hernia had been demonstrated, in order to ascertain definitely the relations of the esophagus to the herniated portion of the stomach.

It is obvious at once that in such a study care must be exercised to eliminate other lesions which might simulate a paraesophageal hernia. The differential diagnosis has been covered so thoroughly in other papers[1, 10, 11, 13, 16, 18] that it is unnecessary again to review it here. Suffice it to say that diverticula of the distal end of the esophagus or of the cardiac end of the stomach can be excluded with ease. Likewise eventration of the diaphragm and other types of diaphragmatic hernia can be differentiated readily. The most confusing picture is presented by those cases in which the cardiac end of the esophagus is dilated and is somewhat delayed in its emptying. This occurs as a result of the inspiratory movement of the diaphragm, producing a

temporary constriction at the hiatus which, with the contraction of the esophagus above, produces a large rounded distention of a portion of the esophagus fittingly termed the "esophagus-bauche" by Sauerbruch, Chaoul and Adam[14] or the "cardiac antrum of the esophagus" by Wagner.[18] It may also occur when the cardiac end of the esophagus is open and there is marked regurgitation from the stomach into it. The latter phenomenon, very common in pregnant women, presented in a few cases some difficulty. Nevertheless, a correct diagnosis can usually be made if certain points are kept clearly in mind. These are: first, the herniated portion of the stomach should be visible when the esophagus is empty; second, the esophagus often can be seen coiled up about the hernial sac; third, if the patient is kept in the same position, the herniated portion of the stomach will remain filled with barium for some time, while the esophagus will empty itself. Furthermore, the observation of the folds of mucous membrane of the stomach, larger and more irregular than those of the esophagus, extending into the hernial sac is an important differential sign. This has been emphasized most strongly by Berg;[5] and in spite of the objections raised to it by Sauerbruch, Chaoul and Adam,[14] we believe it to be of considerable significance. Wagner[18] discusses this differential diagnosis in greater detail.

TABLE I

RESULTS OF ROENTGEN EXAMINATION OF PREGNANT WOMEN FOR HIATUS HERNIA

Multipara examined	116	Hernias present	21	Positive cases	18.1%
Primipara examined	79	Hernias present	4	Positive cases	5.1%
Total cases examined	195	Total hernias	25	Total positive cases	12.8%
Positive cases reexamined	10	Hernias present	3		
Age of positive cases 19 to 40 years. Average age 28 years.					

The results of these examinations in 195 pregnant women are given in Table I. It should be noted that 18.1 per cent of the multipara showed evidence of hernia of some degree. In a series of this size, the probable error of such an incidence would be plus or minus 2.4 per cent. This frequency compares most strikingly with the approximately 1 per cent of hernias seen among our own gastrointestinal patients on whom we used much the same technic of examination. The difference is so great that there are 425,000 chances to one that it is not due to sampling. The marked difference in the incidence in the multipara as compared to that in the primipara, in whom only 5.1 per cent showed hernias, is also notable as indicating the result of repeated abdominal distentions. While this difference is not so great as the one above, nevertheless, the chances are 300 to 1 that it is not due to sampling.

Of the twenty-five positive cases, ten were reexamined at from one to eighteen months after parturition. In only three of these could the hernia again be demonstrated, although the technic of examination was exactly the same.

The significance of these findings has become more pertinent since a new series of papers has appeared on hiatus hernia. In 1931 Berg[5] again noted the frequency of the condition especially associated with a particular clinical syndrome which appeared to be characteristic. In 1932 von Bergmann[17] and Knothe[8] reported on the same subject in great detail. The former developed a description of an "epiphrenal syndrome," including particularly angina-like attacks, which he assigned to pressure of the hernial sac against the heart. Animal experimentation, using balloons in the hiatus, seemed to confirm his theory. Von Bergmann also gave the opinion that this condition would eventually be recognized to be as important as duodenal ulcer or cholecystitis in the production of abdominal symptoms especially in elderly individuals. In fact, Knothe,[8] from the same clinic, reported observing 300 cases in one year, comprising about 8 per cent of all the roentgen examinations of the stomach which were made. These included, however, both a weakness or insufficiency of the esophageal hiatus and an actual herniation. These investigators consider shortening of the esophagus from muscle contraction, spasm, or fibrosis as an important factor in the production of this condition.

Schatzki,[15] who has reported also on the frequency of small herniations, has presented evidence to indicate that they can almost always be demonstrated in aged individuals. By the use of manual pressure over the abdomen in 30 patients over the age of sixty-five years, he was able to visualize hiatus hernias in fourteen. In the remaining sixteen he inflated the colon with gas which apparently resulted in the appearance of a hernia in eight more, so that 73.3 per cent of his cases finally showed evidence of herniation. To substantiate his contention, he presented the autopsy findings in two cases. Koppen and Frank[9] studied the anatomy of the diaphragm in this region with particular attention to the changes which may occur with age, especially the increased mobility of the subdiaphragmatic portion of the esophagus and the upper end of the stomach.

Sauerbruch and his associates[14] have taken sharp issue with the aforementioned investigations. They assert that the observations of von Bergmann,[17] Knothe,[8] Berg,[5] Schatzki[15] and others are entirely in error. They believe that the findings reported are due to dilatations of the lower end of the esophagus as described above, and are not at all true hernias. A critical review of this controversy by Barsony[4] indicates that there may be a middle ground between the two.

Further evidence from extensive anatomical studies has been reported by Anders and Bahrman.[2] They conclude that there are two

types of cases included in Åkerlund's third group of hiatus hernias. One is a true hernia with a definite sac, a relatively uncommon finding. The other is a simple weakness of the hiatus which permits the intra-abdominal portion of the esophagus to be drawn up into the thorax where it becomes dilated, producing an "epiphrenal glocke." The latter, they believe, is the phenomenon which is so common in old age, and it is probably a physiologic mechanism. While it may very well be true that the displacement and dilatation of the intraabdominal portion of the esophagus, described by Anders and Bahrman,[2] accounts for the findings reported by Knothe[8] and Schatzki,[15] we do not believe it explains our findings in pregnant women. The distinction between this condition and an actual herniation has been made, as outlined above, in every case; so we believe that the portion of the gastrointestinal tract visualized above the hiatus, in our cases, is truly a part of the stomach.

The findings we are reporting would seem to indicate clearly that increased intraabdominal pressure, exerted over a long period of time at repeated intervals, will produce these small hernias. The disappearance of the hernia in over two-thirds of the patients who were reexamined indicates the transient character of this condition and further confirms the theory that there is some weakness in the hiatus which may succumb to a marked increase in intraabdominal pressure.* Apparently the removal of this pressure produces a restoration to the normal. The relatively young age of our patients in whom hernias were found seems to indicate that age is not so important a factor as Schatzki, Koppen and Frank, and von Bergmann believe. It would seem from this evidence that increased intraabdominal pressure will produce this type of hernia even in young individuals. It should be noted here that both Harrington[6] and Richardson[12] have observed in many patients of various ages during exploratory operations an abnormally large esophageal hiatus although no hernia was present. No doubt in such individuals the occurrence of repeated pregnancies would tend to produce an actual herniation through this enlarged opening.

Finally, we attempted to determine whether there was any correlation between the gastric symptoms of these pregnant women and the presence or absence of a hernia. No such correlation could be determined. There was apparently a much greater tendency to have pyrosis and gastric distress in those individuals who showed simply marked degrees of regurgitation into the esophagus.

It seems justifiable from these findings to conclude that pregnancy, especially when repeated, is at least an exciting cause for the development of small hernias of the stomach through the esophageal hiatus. It may be concluded also that repeated increases in intraabdominal pressure superimposed upon some other factor, most probably a con-

genital weakness in the hiatus, even in young individuals, will produce a hiatus hernia. On the other hand these hernias may disappear spontaneously and do not appear to be an important cause of gastrointestinal symptoms in pregnant women.

SUMMARY

Roentgen examination of the stomach was done on 195 women in the third trimester of pregnancy. Small hernias through the esophageal hiatus were found in 18.1 per cent of the multipara and in 12.1 per cent of all the cases. In seven of the positive cases the hernia was not demonstrable after parturition. There was no definite correlation of symptoms with the presence of the hernia.

Increased intraabdominal pressure, such as is produced by pregnancy, especially when repeated, appears to be an important exciting cause for the production of esophageal hiatus hernias, even in young individuals.

We wish to express our indebtedness to Dr. J. C. Litzenberg, chief of the Department of Obstetrics and Gynecology of the University of Minnesota, and to Dr. J. A. Urner of the Minneapolis General Hospital, for their kindness and cooperation in placing clinical material at our disposal.

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DISCUSSION

DR. HARRINGTON.—Dr. Rigler has brought out an important point in the etiology of paraesophageal diaphragmatic hernias in that they may be caused by increased intraabdominal pressure as produced, in his group of cases, by pregnancy. It was formerly thought that this type of hernia was practically always the result of some serious injury. While it is true that in about 10 per cent of cases, patients relate their symptoms due to some injury, it is possible that a small herniation was present before the injury occurred and was augmented by the increased intraabdominal pressure associated with the accident. I believe that anything which causes a constant marked increase in the intraabdominal pressure may be the cause of a paraesophageal diaphragmatic hernia. In some instances I believe obesity alone may be the cause.

I have been interested for several years in examining the esophageal hiatus routinely during the course of upper abdominal operations in an effort to determine what the normal size of the esophageal opening should be. In about 50 per cent of cases, no opening could be felt around the esophagus, and in about 50 per cent of cases two or three fingers could be inserted through the opening in the diaphragm around the esophagus; up to two fingers, I believe, are within normal limits. Cases in which three fingers can be inserted along the esophagus, I believe, are potential hernias, and this group of patients should be x-rayed postoperatively. Occasionally a true hernia will be found in this group of cases. This routine examination of the esophageal hiatus is particularly important in gallbladder and stomach cases in which the operative exploration does not reveal sufficient pathology to substantiate the clinical symptoms; as in a certain percentage of these cases it is found that the symptoms are due to a clinically unrecognized diaphragmatic hernia. In cases in which the symptoms are marked, the hernia should be repaired surgically; since the results of operative treatment of these cases are very satisfactory. In those cases in which there is a large congenital defect of the diaphragm the hernia should be repaired with fascia lata from the leg. In all cases, I prefer the abdominal approach.

DR. RIGLER.—Dr. Eggers asked me whether these hernias go to the left or to the right of the esophagus; they are almost invariably to the left of the esophagus, as I showed in the slides.

CHANGES IN VENOUS PRESSURE AFTER THORACOPLASTY —ITS SIGNIFICANCE IN RELATION TO THE EXTENT OF RIB REMOVAL*

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DURING the past year and a half we have been interested in studying the changes in venous pressure following thoracoplasty in a group of patients with pulmonary tuberculosis. The theoretical value of venous pressure measurements in thoracic cases is twofold. First, as had been emphasized by Eyster,[1] generalized elevation of venous pressure is a fairly delicate index of early degrees of cardiac failure. The value of venous pressure measurements in the diagnosis of even slight cardiac embarrassment following pneumothorax and similar collapse procedures in tuberculous patients has frequently been pointed out. Second, pressure changes within the thoracic cage, either intrapleural or extrapleural, may cause local elevation of venous pressure on one side of the body only. This is probably brought about by transmission of pressure to the upper mediastinum with partial mechanical obstruction of the venous return through one innominate vein. This relation of unilateral venous pressure elevation to intrathoracic pressure has been well established by animal and human research investigation.[2] It has also been noted in observations of venous pressure recorded during pneumothorax therapy.[3] In these cases sudden increase in intrapleural pressure on one side has been found to cause unilateral elevation of the venous pressure on the same side. The venous pressure returns to normal when the intrapleural pressure has been adjusted to a more normal status. In several cases we have observed a marked elevation of venous pressure on the operated side immediately following phrenicectomy, which subsided to normal within twenty-four hours when the intrapleural pressure became adjusted to the new position of the diaphragm. Through this mechanism changes in the peripheral venous pressure may be of considerable significance in detecting changes in intrathoracic tension, and especially in indicating the presence of excessive unilateral pressure against the mediastinum. This unilateral mechanical effect on venous pressure has not been emphasized in most studies of this subject. It is precisely this effect, however, which we have found most significant in following the effects of thoracoplasty.

*From the Department of Thoracic Surgery, Lahey Clinic, Boston.
Presented before the Seventeenth Annual Meeting of the American Association for Thoracic Surgery, Boston, Mass., May 31, June 1 and 2, 1934.

Previous studies, chiefly reported in the European literature,[3] of the relation of venous pressure to collapse procedures for tuberculosis have shown that any elevation in venous pressure during collapse therapy is an unfavorable sign. Elevation of the venous pressure above 12 cm. of water at the level of the right auricle has been stated to be a definite sign of intolerance to the degree of collapse instituted. With this elevation of venous pressure in pneumothorax cases, whether the intrapleural pressure be positive or negative, symptoms of excessive pressure against the mediastinum occur, which are relieved only when the pneumothorax has been lessened and the venous pressure returns to normal. Villaret and Desoillé[4] were so impressed by this relation that they have described increased venous pressure as the signal of alarm which precedes the phenomena of intolerance to collapse therapy in pneumothorax.

Similarly, in our studies of thoracoplasty patients, we have been impressed with the fact that elevation of venous pressure is an unfavorable indication. In patients showing unilateral elevation of venous pressure before operation, we have usually found some abnormal complication such as hydropneumothorax or excessive fibrosis. Patients with normal venous pressures preoperatively who developed elevated pressure after operation, showed definite signs of poor toleration of the thoracoplasty collapse. These patients complained of dyspnea and excessive pressure in the chest, showed cyanosis, rapid pulse, and in some cases paradoxical respiratory movements of the chest wall. As these symptoms and signs of poorly tolerated collapse subsided, the venous pressure returned to normal.

TABLE I

VENOUS PRESSURE STUDIES IN INTRATHORACIC DISEASE

Total cases studied		112
Pulmonary tuberculosis	65	
Other pulmonary lesions	7	
Intrathoracic goiter	30	
Mediastinal tumors, fibrosis, etc.	10	
Cases thoracoplasty for pulmonary tbc		53
Elevated v.p. preoperatively	7	
Normal v.p. preoperatively	46	
Cases thoracoplasty with completed postoperative v.p. records		38
Elevated v.p. preoperatively	3	
Normal v.p. preoperatively	35	

As shown in Table I, we have made venous pressure studies in 112 patients who had an intrathoracic lesion. Sixty-five of these patients had pulmonary tuberculosis, and 53 of the group were treated by thoracoplasty. Of the thoracoplasty group satisfactory venous pressure records after operation have been completed in 38 patients. This report deals largely with the findings in these 38 patients.

In all of these cases venous pressure measurements were made before and at intervals after operation. The measurements were recorded on a special chart together with other data concerning the patient's condition

THORACIC STUDY CHART - LAHEY CLINIC

Cl. No. 32598

D.B.Hosp.No. 66413 Examination Date: March 19, 1933

Diagnosis: Pulmonary Tuberculosis Left
Operation: Left Upper Thoracoplasty Ribs 1,2,3

Name: Mr. J. D.

Age 27 (M.) F. Dur.Dis. 2 yrs. Dur. San: 1/2 yrs. T.B.Class: III Prognosis Life (Poor) Fair (Invalid) Good Cure

Status	Pre-op.	2nd Day	4th Day	1 Wk.	2 Wks.	3 Wks.
Pulse Ave.	100	120	110	85	85	
Temp. Ave.	98	101	99	99	98	
Resp. Ave.	20	20	20	20	20	
Cough	slight	—	—	—	—	
Sputum Organ.	+					
Sputum Color	bloody					
24 Hr. Amt.	< 1/2 oz.		1/2		1/4	
Cyanosis	0	0	0	0	0	
Dyspnea	0	0	0	0	0	
B. P.	110/80	110/85	105/70	110/80	110/80	
Vital Capacity	2900					
Venous Pressure Rt.	7	9	11	9	8	
Venous Pressure Lt.	7	11	12	7	8	
Sed. Rate						
Blood	70			90	80	

Fig. 1.—Research chart used in tabulating venous pressure measurements and other clinical data in tuberculosis patients before and after operation. The chart illustrated shows a smooth convalescence from a first-stage left upper thoracoplasty of three ribs. Venous pressures remained normal.

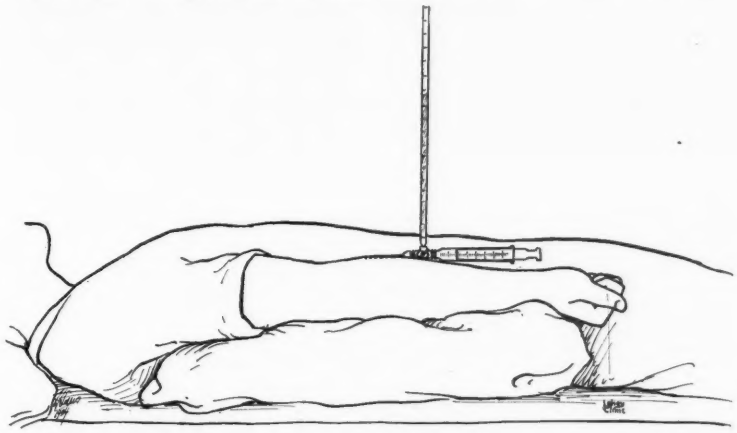


Fig. 2.—Drawing of apparatus used for direct venous pressure measurement. The arm is placed so that the brachial vein is on an approximate level with the right auricle. The needle in the vein is connected to a three-way valve which is connected with a syringe containing saline solution and with a spinal manometer tube or other calibrated glass tube. After inserting the needle in the vein a small amount of blood is drawn back into the syringe coloring the saline. The manometer is then filled with this colored solution. Next, the valve is turned to connect the manometer with the vein and the level of the solution falls to the level of the pressure in the vein. As a check the solution is then drawn lower in the manometer (using the syringe) and the blood in the vein allowed to push the solution up until it again reaches the level of the vein pressure. We have found this a simple and accurate method which employs materials readily available in any hospital.

at the time the venous pressure was taken (Fig. 1). The pressure was taken routinely in the right and left brachial veins. Because of the effect of gravity on venous pressure, the arm was always placed at the side of the chest so that the vein was at an approximate level with the right auricle. The direct method of venous pressure measurement was used, with the apparatus illustrated in Fig. 2. A venous pressure of more than 12 cm. of water was regarded as abnormally elevated.

THE EFFECT OF FIRST-STAGE UPPER THORACOPLASTY

Of the total group of 53 thoracoplasty patients, seven had elevated venous pressures preoperatively on one side. Of these seven cases, two had pneumothorax, two had hydropneumothorax, and two showed unilateral extensive fibrosis of the upper chest with marked pull on the mediastinum. In one case, the x-ray picture showed no definite evidence of a mechanical disturbance in the chest. In three of this group, venous

TABLE II

EFFECT OF THORACOPLASTY IN 3 CASES WITH UNILATERAL ELEVATION OF VENOUS PRESSURE BEFORE OPERATION

	TYPE OF LESION	VENOUS PRESSURE ON OPERATED SIDE BEFORE OPERATION	AFTER OPERATION
Miss P. L.	Hydropneumothorax	15	4
Mr. J. C.	Extensive fibrosis	15	5
Miss E. Q.	Exudative tuberculosis	16	7

pressure studies were made after operation, and a return to normal following thoracoplasty was noted (Table II). Subsequent roentgenogram studies showed that the thoracoplasty had corrected the abnormal mechanical conditions in the chest.

TABLE III

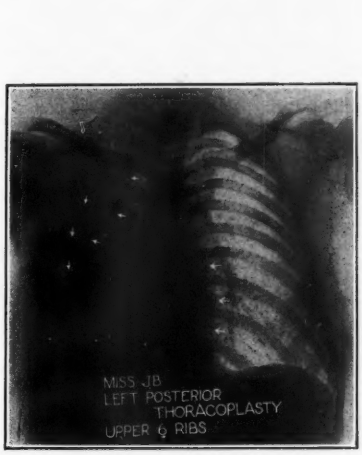
EFFECT OF THORACOPLASTY IN 35 CASES WITH NORMAL VENOUS PRESSURE (LESS THAN 12 CM.) BEFORE OPERATION

	SECOND DAY POSTOP. NO. CASES	PER CENT	SEVENTH DAY POSTOP. NO. CASES	PER CENT
Normal venous pressure	24	69	30	86
Elevated venous pressure	11	31	5	14

Of the patients with normal preoperative venous pressures, postoperative studies have been completed in 35. Eleven of these cases, or approximately 30 per cent, were found to have elevation of the venous pressure on the operated side when readings were taken two days after the first-stage thoracoplasty. Elevation of the venous pressure in these cases was accompanied by an unfavorable clinical reaction to operation. In the remaining 24 cases, the venous pressure on the second day postoperative was normal, and in these cases there was also little reaction to the operation (Table III).

RELATION OF VENOUS PRESSURE ELEVATION TO DEGREE OF COLLAPSE AND EXTENT OF RIB REMOVAL

In the cases showing an elevated venous pressure, the elevation in pressure and the associated unfavorable reaction to operation seemed to be definitely related to the amount of upper chest collapse produced. In general the greater the collapse the higher the postoperative venous pressure. X-ray pictures taken postoperatively in the eleven cases of elevated venous pressure uniformly showed a marked degree of collapse. In the majority of these cases the trachea and mediastinal structures were found to be deviated toward the contralateral chest. Similarly in the cases of normal postoperative venous pressures, x-ray pictures showed



A.

B.

Fig. 3-*A*.—Miss J. B. X-ray picture taken after left upper thoracoplasty, six ribs, short segments. As indicated by the arrows the lung is only moderately collapsed and the heart and mediastinum are not shifted greatly. (Venous pressure before operation, 5 cm.) Venous pressure on operated side was 12 cm. on the second postoperative day, 8 cm. two weeks after operation.

Fig. 3-*B*.—Miss M. F. X-ray picture taken after left upper thoracoplasty six ribs, long segments. There is complete collapse of the upper two-thirds of the lung. Heart and mediastinum are markedly displaced. Venous pressure before operation, 7 cm. Venous pressure on operated side was 20 cm. the second day postoperatively, 16 cm. two weeks after operation. Venous pressure on the opposite side remained normal (8 cm.).

(Note: We have long since discontinued doing the type of thoracoplasty illustrated in these x-ray pictures in which the transverse processes are left in. Inadequate collapse as in Fig. 3-*A* frequently follows this type of operation.)

only a moderate degree of collapse, usually without displacement of the mediastinum. This contrast between the degree of collapse associated with elevated and with normal postoperative venous pressures is illustrated by the x-ray pictures shown in Figs. 3 and 4. It must be emphasized that the venous pressure in these cases was elevated on the operated side only, the venous pressure on the contralateral side being normal.

This means that the venous pressure change must be related to the local effect of the thoracoplasty rather than to generalized disturbance of the venous circulation from cardiac embarrassment or postoperative shock. The change was not related to serum collection in the wound because all wounds were drained.

The close relation of the postoperative elevation of venous pressure to the degree of collapse was further brought out by a comparison of the height of venous pressure postoperatively with the extent of rib removal at operation. (The amount of collapse obtained is obviously proportional to the number and length of ribs resected.) In cases in which

A. *B.*

Fig. 4-*A*.—Mr. R. C. X-ray picture showing moderate collapse of the left upper chest following three-rib upper thoracoplasty. Heart and mediastinum are not shifted. Venous pressure before operation 10 cm. Venous pressure on second postoperative day, 10 cm.

Fig. 4-*B*.—Mr. B. A. X-ray picture showing marked collapse of upper chest following five-rib upper thoracoplasty on the right removing long segments of all five ribs. Heart and mediastinum displaced. This patient had a very stormy convalescence with rapid pulse, dyspnea, cyanosis, and paradoxical respiratory movements of the right upper chest for two weeks after operation. Venous pressure before operation, 7 cm. Venous pressure on operated side was as follows: second day—18 cm., seventh day—18 cm., fourteenth day—13 cm.

few ribs were removed, the venous pressure was unchanged following operation. When more than four upper ribs were removed, the postoperative pressure was frequently elevated. In Table IV the percentage

TABLE IV

RELATION OF ELEVATION OF VENOUS PRESSURE TO EXTENT OF RIB REMOVAL

NO. RIBS RESECTED	PERCENTAGE CASES SHOWING V.P. ELEVATION POSTOPERATIVE	
	SECOND DAY POSTOP.	SEVENTH DAY POSTOP.
3	20%	8%
4	25%	9%
5	66%	30%
6	66%	50%

of cases showing elevated venous pressure on the second and seventh days postoperatively has been tabulated in relation to the number of ribs removed. The percentage of elevated venous pressures was extremely high after a five- or six-rib thoracoplasty and relatively low when a more conservative rib removal had been done. Fig. 5 illustrates the relation of venous pressure to the extent of rib removal from another angle. In Fig. 5, all the venous pressures taken on the second day postoperatively in this group of patients have been charted. It can be seen that after conservative upper thoracoplasty removing only four ribs or less, almost all the venous pressures were below normal limits, whereas after thoracoplasty of five or six upper ribs almost all the venous pressures were above normal.

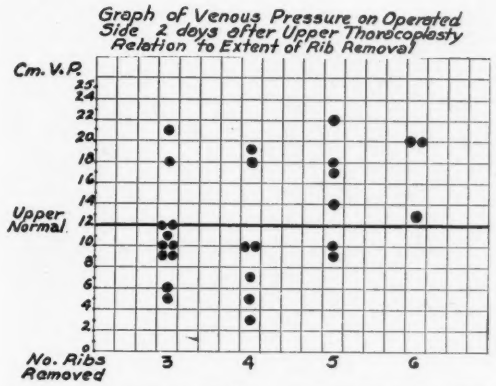


Fig. 5.—Chart of venous pressure readings on the second day after thoracoplasty. The predominance of normal pressures after conservative rib removal and of elevated pressures after extensive rib removal is shown.

EFFECT OF SECOND-STAGE THORACOPLASTY

In ten of the patients additional ribs were resected at later operations. In seven cases a time interval of six weeks or longer elapsed between the first stage and the second. The second stage in each case consisted of a lower posterior thoracoplasty. In these cases, the venous pressure

TABLE V

EFFECT OF SECOND-STAGE THORACOPLASTY ON VENOUS PRESSURE IN 7 CASES WITH INTERVAL OF MORE THAN SIX WEEKS FOLLOWING FIRST STAGE

PATIENTS	VENOUS PRESSURE READINGS			
	PREOPERATIVE		POSTOPERATIVE	
	R.	L.	R.	L.
Mr. R. C.	4	9	4	3
Mr. J. D.	8	9	8	8
Miss J. B.	9	9	11	11
Miss V. R.	7	9	6	8
Mr. H. A.	8	11	8	9
Miss P. L.	8	9	7	4
Mr. R. C.	10	11	10	10

was unaffected by the operative procedure, although an extensive collapse was obtained (Table V). The long time interval allowed the upper area of collapse to stiffen. This formed a protective shell outside the upper mediastinum, and postoperative x-ray pictures showed little shift in the position of the trachea or mediastinum following the second-stage procedure (Fig. 6). In two cases in which lower thoracoplasty alone was performed without previous upper thoracoplasty, the venous pressure was also unaffected.

In three cases, a second-stage lower thoracoplasty was performed sooner than two weeks after the first stage before the upper chest wall

Fig. 6.—Mr. R. C. X-ray picture following second-stage thoracoplasty, ribs 4, 5, 6, 7. Operation done six weeks after first stage. X-ray of first stage in this patient is shown in Fig. 4-A. Comparison of these x-ray picture shows that the protective shell of the upper collapse area has not shifted appreciable following second-stage operation. Venous pressure on operated side before operation—10 cm.; after first stage—10 cm., after second stage—10 cm.

had had time to stiffen. This was purposely done because it was then considered necessary in order to obtain a satisfactory collapse. In all three cases, the venous pressure was markedly elevated postoperatively

TABLE VI

EFFECT OF SECOND-STAGE THORACOPLASTY ON VENOUS PRESSURE IN 3 CASES WITH INTERVAL OF LESS THAN TWO WEEKS FOLLOWING FIRST STAGE

PATIENTS	VENOUS PRESSURE READINGS			
	PREOPERATIVE		POSTOPERATIVE	
	R.	L.	R.	L.
Mr. V. A.	5	8	16	8
Miss D. V.	9	14	12	21
Mr. J. L.	7	10	10	17

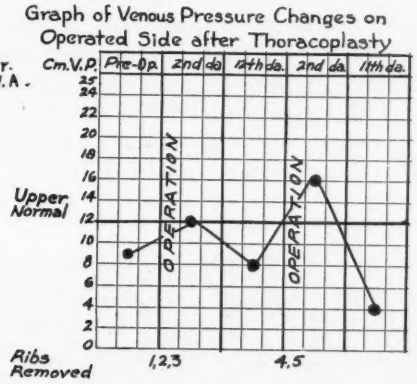


Fig. 7.—Graph of the venous pressure changes recorded on Mr. V. A. Note slight rise after first stage, 3-rib thoracoplasty but not above normal. Second-stage operation done fourteen days after first. Venous pressure on operated side was 16 cm. (7 cm. on opposite side) on second postoperative day. Venous pressure normal eleven days later.

Fig. 8.—Miss D. V. X-ray picture after 3-rib upper thoracoplasty (unusually long segments). Marked collapse of left upper chest with some displacement of mediastinum. V. P. left, second postoperative day, 21 cm. (right, 8 cm.); twelfth postoperative day, V. P. left, 14 cm. (V. P. preop., 8 cm.).

(Table VI). The effect on the venous pressure and also the clinical reaction to operation was almost as severe as if both the upper and lower stages had been performed at one operation. For example, in the case of Mr. V. A. a three rib upper thoracoplasty had been well tolerated without effect on the venous pressure (Fig. 7). A second-stage thoracoplasty was done fourteen days later, removing two more ribs. Following this, the venous pressure was elevated to 16 cm. on the second day, and the patient was moderately dyspneic. The effect was the same as if five ribs had been removed at one time.

The sequence of events in another of these cases, Miss D. V., was especially instructive and deserves special comment. Miss D. V., aged seventeen years, had bilateral tuberculosis chiefly on the left side. A first stage left upper thoracoplasty was done removing the three upper ribs.

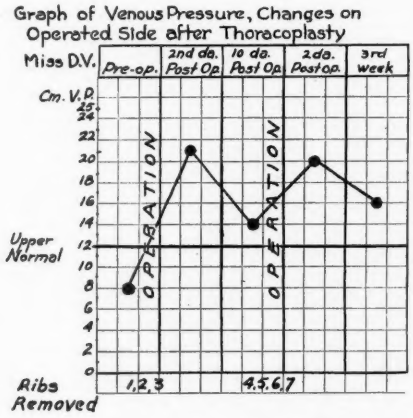


Fig. 9.—Graph of venous pressure record of Miss D. V., showing relation of elevation of venous pressure on operated side to the thoracoplasty procedures.

An unusually long segment of the third rib was removed, producing a more extensive collapse than usual (Fig. 8). On the second day after operation, the venous pressure on the left was 21 cm., on the right 8 cm. (Fig. 9). Twelve days after operation, the venous pressure on the left was still 14 cm., on the right 9 cm. We did not appreciate the warning of this elevated pressure; and at this time a second-stage thoracoplasty was performed, resecting moderately long segments of the fourth, fifth, sixth, and seventh ribs. The patient had an immediate, very severe reaction to this procedure. She was dyspneic and intensely cyanotic. The mediastinum and heart were pushed far over to the contralateral side, and the lower lobe on the right was partially compressed (Fig. 10). The venous pressure was over 20 cm. on the second day after operation, and at the end of three weeks the venous pressure on the left was still 16 cm. while the venous pressure on the right was 7 cm. A good

collapse was obtained in this case, with improvement also on the contralateral side, but it almost cost the patient her life. The same result could probably have been obtained by more conservative surgery spread over a longer period of time. The unusual elevation of venous pressure after a three-rib upper thoracoplasty should have indicated that the patient already had a greater collapse than she could comfortably handle. Further operation should have been postponed until the venous pressure was normal.

Fig. 10.—Miss D. V. X-ray picture three weeks after second-stage thoracoplasty (ribs 4, 5, 6, 7). Extensive collapse. Heart and mediastinum displaced to right. V.P. left, 16 cm., right, 7 cm.

CONCLUSIONS

In reviewing these observations on changes in venous pressure after thoracoplasty, we may summarize as follows:

Venous pressure estimations were made before and after operation in a series of thoracoplasty patients. The significant alterations of venous pressure which were found occurred on one side only, or predominantly on one side. It is important to distinguish between such unilateral elevation of venous pressure which is of mechanical origin, and generalized elevation of venous pressure of cardiac origin. In none of the cases showing unilateral elevation of venous pressure was there

evidence of cardiac insufficiency. It has been assumed, therefore, that the venous disturbance noted was due to local mechanical conditions resulting from the disease or brought about by the collapse procedure.

The following points warrant emphasis:

1. In those patients showing an elevated unilateral venous pressure preoperatively the elevated pressure was corrected by thoracoplasty.

2. When the first stage of the operation is limited to the upper three or four ribs, there is little likelihood of disturbing a normal preoperative venous pressure.

3. The resection of more than four ribs (completely or long segments) frequently disturbs the venous return on the operated side.

4. When the second-stage thoracoplasty follows shortly upon the first (within the first two weeks), an elevated venous pressure on the operated side may be expected.

5. We have been impressed with the relationship between an elevated venous pressure postoperatively and what was considered poor toleration to the amount of collapse provided. An elevated venous pressure has seemed to indicate an excessive degree of collapse.

The knowledge of the status of the venous circulation as obtained by venous pressure measurement has seemed to us to be of value for two reasons: First, it has aided in estimating the extent of rib removal which will insure a wide margin of safety during convalescence. Second, it has been one of the factors which has convinced us that the second operation should not be done so soon after the first that the effect of the two equals that brought about by a too extensive single operation.

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A CRITICAL STUDY OF SOME UNSATISFACTORY RESULTS FROM THORACOPLASTY OPERATIONS*

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WE HAVE noted from time to time in the course of our work that there have been cases of pulmonary tuberculosis in which the patients had been subjected to the operation of thoracoplasty and the result hoped for had not been obtained. I hope that by reviewing this group of cases we may be able to acquire information that will aid us in avoiding such disappointments in the future. A study of any series of successful cases should enable one to repeat the successful performance if one continues to work under exactly similar conditions. On the other hand, it is not at all unlikely that the surgeon is dealing with a different group of conditions in those cases in which the results are disappointing; otherwise, the application of the measures that lead to a success in one group of cases should lead to similar success instead of disappointment in the second group of cases. The study of the failures, therefore, becomes of great importance.

I am confident that I have not been disappointed more frequently with the results of thoracoplasty operation performed for pulmonary tuberculosis during the past eleven years than have other men doing thoracic surgery over the same period. I should like to state that I have no desire to perpetuate the impression that seems to prevail in the minds of some men, that a cavity is never closed by thoracoplasty! In fact, when I came to the selection of cases on which to base this discussion I was agreeably surprised to find that the closure of cavities was the rule and that a failure to close a cavity was the rare exception. Even in my earlier experiences, which fell at a time when most men were still very uncertain as to the advisability of introducing any form of collapse for pulmonary tuberculosis, the results of my efforts were gratifying. It is the small group of cases which were a source of disappointment that I wish to study.

CASE 1.—Miss P., twenty-seven years of age, weight 88 pounds, temperature 102°, pulse 100. Her illness began five years previously with a hemorrhage of a moderate amount. At the time of her admission she had a slight cough in the morning, with positive sputum, and presented evidence of a large cavity and multiple smaller cavities in the right upper lung field. She was subjected to a thoracoplasty, upper stage, posterior, with resection of five ribs. The ribs were small but somewhat harder than would be expected in one of her age. Six months later x-ray studies

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showed a honeycomb area significant of cavities in the right upper lobe. The posterior thoracoplasty was then completed and a phrenic exeresis performed on the right. After one and a half years' stay in the institution, the patient was discharged with a positive sputum and a temperature of 98.8° to 101.0°, pulse 114 to 130, and her weight was 71 pounds. The patient died of a spread of the condition to the other lung.

A study of the x-ray findings in this case brings out the following points of interest: It is to be noted that following the posterior upper stage thoracoplasty the posterior ends of the ribs were resected reasonably close to the transverse process of the spine. However, the anterior stumps of these ribs were of such marked rigidity that they failed to collapse and projected in such a manner that during regeneration of the resected portion of the ribs these anterior ends, together with the posterior stumps, served as buttresses which supported the regenerated ribs in much the same manner that the cables of a swinging bridge are supported. I had accomplished by this process, therefore, only a flattening of the posterior segment of the cavities that were present in the apex of this lung. When later resection of all the lower ribs was carried out, some additional collapse was obtained; but it is apparent that the regenerated portion of the upper ribs had become so firm that no further collapse was

Fig. 1. Fig. 2.

Fig. 1.—Miss P., following upper stage posterior thoracoplasty. Note the incomplete collapse that has been obtained, with a residual cavity occupying an area between the third to the sixth ribs posteriorly.

Fig. 2.—Note that in spite of the completed posterior thoracoplasty there still remains very little additional collapse of the upper lung field. In addition there has appeared evidence of disease in the opposite lung.

obtained over the cavities which it was our desire to close. In fact, the result obtained by this complete posterior thoracoplasty was not more than 60 per cent of collapse of the diseased lung. If by chance the interference offered by anterior stumps could have been avoided, the result might have been a complete collapse of the chest wall together with the cavity containing lung, and the lower portion of the posterior thoracoplasty which did no good at all might never have been performed. This might have been accomplished had I removed the anterior stumps especially of the first, second, and third ribs in their entirety including the costal cartilages. There would then have remained no buttresses to support the regenerating ribs.

CASE 2.—Mr. J., thirty-four years of age, entered the institution with a history of illness extending back seven months with night sweats, cough, one cup of sputum daily, no loss of blood, and no loss of weight, temperature 98° to 99°, pulse 82 to 100, and positive sputum. Physical signs and x-ray examination showed evidence of a cavity in the right lung opposite the fifth and sixth ribs posteriorly with exten-

sion of the disease throughout the lower two-thirds of the right lung, and some involvement of the upper portion of the left lung. A thoracoplasty with removal of the posterior segments of the upper six ribs was performed. Following this procedure there remained evidence of a cavity in the right upper lung field, 6 cm. by 8 cm., with a smaller cavity just below, and there was an extension of the lesion into the left lung. The sputum remained positive and his temperature was up to 99°. The patient left the hospital, against advice, to return to Norway before further operative work could be carried out.

A study of the x-ray findings in this case brings out the following points of interest: It is to be noted that there is a huge cavity occupying the upper portion of the right lung field extending down to the sixth interspace posteriorly. The cavity occupies practically the whole of the upper lobe. The ribs are very large and are very rigid with very little give in the cartilages. The progress x-ray studies show that there had been a resection of the posterior segments of the upper six ribs. The posterior stumps were long and projected well out over the area occupied by the

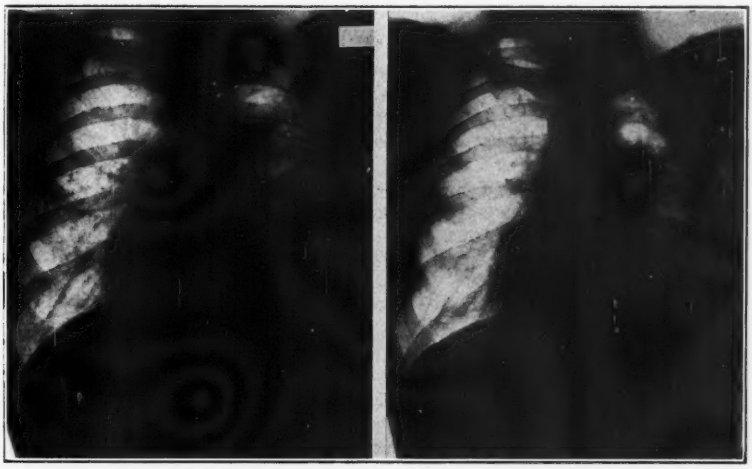

Fig. 3. Fig. 4.

Fig. 3.—Mr. C. Note the large cavity occupying an area extending from the first to the sixth interspace on the right.

Fig. 4.—Showing the projecting posterior stumps of the resected ribs with only a flattening of the posterolateral margins of the huge cavity.

cavity. In the process of regeneration the regenerating ribs were strung between the projecting posterior stumps and the rigid anterior stumps, both of which served as buttresses to support the regenerating rib which sagged to only a small degree. In this case I have again failed to close the cavity, first, because of the long posterior stumps and, second, because of the rigid anterior segments of the upper ribs which form ledges which prevent collapse of the cavity. Is it not probable that had there been a complete resection of the posterior portions of these ribs, including at least a part of the transverse processes, that the bony frame could have been removed from over all of that portion of the cavity which lies posteriorly and that by a similar removal of the anterior ends of the ribs, with their costal cartilages, up to the edge of the sternum a complete collapse of the chest wall with closure of the cavity might have resulted? It is true that this patient left the institution before the operative procedure had been completed. However, it seems apparent to me that

in this case the most important defect of the procedure was the incompleteness of the removal of the bony frame over the diseased area.

CASE 3.—Mr. C., thirty-five years of age, caught a cold which lasted several weeks, then diagnosed as tuberculosis. X-ray and physical findings on admission showed an advanced bilateral lesion with honeycomb-like rarefactions in the left upper lung field between the first and second ribs, anteriorly. The sputum was three plus, Gaffky. One year later a permanent phrenicectomy was done. A pneumothorax was attempted but was discontinued because the collapse was incomplete. One year later a left posterior thoracoplasty from the first to, and including, the ninth rib was performed and a total length of 116.5 cm. was removed in two operations. The sputum remained positive.

A study of the x-ray findings in this case brings out the following points of interest: This patient shows evidence of multilocular cavitation on the left side extending from the level of the first to the sixth ribs, posteriorly, and scattered throughout the lung field from the mediastinal margin to the lateral chest wall. It is to be noted that the patient had previously been subjected to pneumothorax treatment which had failed to collapse the diseased area, there being not more than 30 per cent collapse obtained at the time. At the time of the operation a complete posterior thoracoplasty was performed with the posterior stumps of the ribs being left long, there being at least one inch of the first, second, and third ribs projecting beyond the transverse processes. A rather long section of rib was removed, so that the anterior ends were somewhat shorter than those of the average case. However, there still remains evidence of multilocular cavitation which is protected from collapse by the projection of the posterior stumps and the overhanging anterior stumps. One other thing should be remembered, that is the rigidity of the bony frame which further interfered with the collapse.

CASE 4.—Mr. F., thirty-four years of age, had pleurisy one year previous to admission. There was no cough or night sweats; temperature was 98.6° to 100°, pulse 100, and he was 25 pounds underweight. A phrenic exeresis was performed on the left. Three months later x-ray studies showed cavitation of the left upper lobe with evidence of tuberculous lesion opposite the first and second ribs. The sputum was positive. A thoracoplasty with removal of the posterior ends of the upper six ribs was performed. The sputum continued positive. One year later a fat transplant to close a cavity on the right was performed with the result that sputum was reduced in amount but remained positive.

A study of the x-ray findings in this case brings out the following points of interest: It is to be noted that in the left lung there is a large cavity extending from the first down to the sixth rib, posteriorly, and occupying the lateral portion of the lung field from the front to the back of the chest. There is also evidence of destruction in the first and second interspaces on the right. A review of the findings after the thoracoplasty had been performed revealed the presence of posterior stumps that projected well out over the cavity area with a slitlike remnant of cavity persisting. The anterior ends of the first, second, and third ribs remained to form ledges behind which the cavity had receded. I again ask the question, would I have been successful in closing this cavity had the resection of the posterior ends of the ribs been carried to the transverse process of the spine and part of the transverse processes themselves been resected, thus removing the posterior ledge which had prevented a collapse of that portion of the cavity? I also feel that it would have been desirable to have removed those sections of the ribs which projected over the cavity anteriorly, that is, the first, second, and third ribs to the border of the sternum.

CASE 5.—Miss E., thirty-six years of age entered the institution with a temperature of 98.8°, pulse 102, and 11 pounds underweight. This patient had been ill with pulmonary tuberculosis for several months, having previously spent thirty months in Arizona for treatment. She had a pneumothorax on the left which never resulted in more than 70 per cent collapse. She developed empyema on the left which was drained after a time, and a complete posterior thoracoplasty was performed. The sputum was negative and remained so. Because of the empyema which had ruptured through the lung, a permanent phrenicectomy was done on this side. The patient developed some gastric distress and continued to empty at times small amounts of sputum with occasional blood streak, but never any tubercle bacilli.

A study of the x-ray findings in this case brings out the following points of interest: It is to be noted that there is roentgen ray evidence of an incomplete collapse of the left lung by pneumothorax with considerable narrowing of the left hemithorax resulting evidently from scar tissue. Following the operative procedure there was a satisfactory collapse of the diseased lung with an apparent closure of the empyema cavity. However, there remained a drainage tube in the pleural space, and it was not surprising that with the lapse of time and the removal of this tube the patient found herself spitting pus which undoubtedly was an evacuation from a residual empyema cavity. This case is presented not because the thoracoplasty failed to give a satisfactory collapse of the diseased lung but because there presents a symptom which one would always be inclined to consider as being due to a pulmonary lesion until proved otherwise. The patient is in good general health and should be working.

CASE 6.—Miss H., thirty years of age, but appeared older by at least ten years. After 392 weeks of chasing the cure she asked for a thoracoplasty but specified that she wanted it done in one or two operations. Sputum was positive, her pulse 100, and temperature 99.6°. Under gas oxygen anesthesia the posterior ends of the upper four ribs were removed from the transverse process of the spine forward to the costal cartilages without immediate change in the patient's pulse, although there was a marked collapse of the apical portion of the lung with free down-drawing of the apex during inspiration and upward blowing during expiration. The patient died of air hunger within eighteen hours after operation.

A study of the x-ray findings in this case brings out the following points of interest: There is a heavily scarred but destructive lesion in the left lung, which extends to the level of the sixth rib posteriorly. There are numerous calcified areas throughout both lung fields outside this area. There is a retraction of the mediastinal contents to the left. Death occurred within such a short time after the operation that the only explanation to be given for it is that the patient had too much done at the first operation. I feel confident from experiences with other patients that had this patient been subjected to a resection of the anterior portions of the first two ribs from the sternal margin lateralward to the midaxillary line and at a later operation the posterior segments of the first two, possibly three, ribs resected and finally segments from two more ribs resected, the result would have been a complete closure of the cavities at this left apex without undue embarrassment of the patient. I feel that the marked excursion of the pulmonary apex was the factor which defeated this attempt.

CASE 7.—Mr. B. P., forty-six years of age, entered the institution 43 pounds underweight with a temperature of 98.9° to 99.4°, pulse 88 to 114, and a positive sputum. He was considered a poor risk, as he had been sick for many months and had followed bed rest alone without other aid. There was a very large cavity occupying practically all the right upper lobe, the lower right lobe being of fairly normal appearance. The left upper lobe was also involved, but no cavities were noted.

Under novocaine anesthesia the anterior ends of the first, second, third, and fourth ribs, including costal cartilages, on the right were removed from the sternum to the midaxillary line without disturbance to the patient. Three weeks later the posterior ends of the first four ribs were removed through the usual paravertebral incision. The patient left the operating room in fair condition. He had a satisfactory afternoon and night but died early the next afternoon with rapid pulse and cyanosis.

A study of the findings in the case brings out the following points of interest: The anterior operation which was performed under novocaine anesthesia with removal of the anterior ends of four ribs from the sternum lateralward to the midaxillary line, was performed without any embarrassment to the patient. Following the resection of the posterior segments of these four ribs his pulse was disturbed and he presented evidence of respiratory embarrassment which I feel was probably due to the fact that the patient had too many ribs removed at this second operation. Had I the opportunity of repeating this procedure I should be inclined to remove only the posterior segments of the upper two, or at the most, the upper three ribs at this second operation. It must be borne in mind that this patient had been in bed over a long period and that he showed evidence of involvement of the opposite lung which, however, had not advanced during the last several months. He was, of course, a bad risk; and inasmuch as I was aware of the fact and was operating on this patient as a last resort, I should have limited the extent of the operation so as to avoid undue load on the patient's poor reserve.

CASE 8.—Mr. H., thirty years of age, who had been under a physician's care as a bed patient for three years, weighed 185 pounds, had a temperature of 98.6° to 99.6°, and a pulse of 110 to 140 on slight exertion. There was no albumin in the urine, but his feet were swollen when he was on them. He had previously undergone a left permanent phrenicectomy with marked elevation of the diaphragm. There remained a very large cavity in the right lung which extended down to the third rib anteriorly. Sputum was positive. Under novocaine anesthesia a resection of the posterior ends of the upper three ribs on the right was carried out. The patient left the operating room in good condition, pulse 100. It is to be noted that the patient received some digitalis throughout his stay in the hospital. The sputum decreased in amount, and one negative and one positive sputum for tubercle bacilli were reported. The patient's pulse remained rapid and he died fifteen days after the operation, the death being due to myocardial failure.

A study of the x-ray findings in this case brings out the following points of interest: There was a huge cavity extending to the level of the third rib and to the sixth rib posteriorly on the right. The cavity was in close proximity to the lateral chest wall. Following the operation the posterior stumps of the ribs were found to be long. However, in spite of this, the cavity had been shoved downward to a very great extent until it then reached down to the seventh rib posteriorly. I am inclined to suspect that because of these very long posterior stumps the end-result would have been unsatisfactory had I been permitted to complete resection of the lower ribs on this side. I was further embarrassed in this case by the fact that the patient had a phrenicectomy performed on the opposite side which had resulted in a marked elevation of the diaphragm and that he had a definite myocardial disease and was overweight. I questioned the advisability of undertaking such an extensive procedure in a patient with this combination of circumstances. However, it is just probable that if I were faced with the same problem again that I would undertake to close the cavity but I would go about it in a different manner. I would first resect the anterior segments of the first three ribs from the sternum lateralward and then divide the posterior operation into about three stages, taking no more than two ribs at any one stage, and I would make a particular point not only of removing the rib

to the transverse process of the spine but also of removing considerable portions of the transverse processes of the spine themselves.

SUMMARY

My unsatisfactory results consist of:

1. Four cases of incompletely closed cavities. There is first the large single cavity which occupies a considerable portion of the upper lung field. It may extend well back into the vertebral gutter or into the anterior lateral part of the upper lung field. Such cavities are not closed by the ordinary paravertebral thoracoplasty, even though all the ribs are removed posteriorly. Especially is this true if too long a time elapses between the stages of the operation so that regeneration and fixation take place between succeeding operations. Also they are not closed when the posterior stumps of the ribs are left long. The presence of the anterior ends is a further handicap. The rigidity of the bony frame seems to be an additional factor.

2. The other type of cavity is the multilocular cavity scattered throughout the lung field in association with considerable scar tissue. The same factors which prevent closure in the large cavities are found to be present in this type of cavity.

3. A case of pus and blood spitting due to a pleurobronchial fistula which did not close after drainage through a thoracotomy wound.

4. Three deaths all due to the fact that I attempted to accomplish too much at one operation. This statement is too modified to the extent that I remind you that two of these patients were very poor risks and that I might have been justified in refusing to operate upon them. However, having undertaken the procedure I feel that I was mistaken in permitting the patients to influence me to the extent that I did more at one operation than I believed to be safe.

CONCLUSIONS

1. I am convinced that in the application of the operation of thoracoplasty in the treatment of pulmonary tuberculosis it is desirable to thoroughly and completely remove the bony frame over the diseased portion of the lung field.

2. The removal of portions of the transverse processes of the spine, together with the anterior ends of the ribs, not only up to the costal cartilages but also including the cartilages and edge of the sternum, will at times lead to satisfactory results when disappointment might otherwise be encountered.

3. Multiple stage operations are to be chosen.

This discussion is based upon a study of cases from the Detroit Tuberculosis Sanatorium. We wish to express our deep appreciation to the Board of Directors and to the superintendent for their loyal support which was sorely needed in our early days.

EXPERIENCE WITH PNEUMOCAVERNOLYSIS*

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FOR the purpose of completeness it becomes necessary briefly to summarize the material on this subject. The first reference to pneumocavernolysis is found in the *American Review of Tuberculosis*,[1] in a paper read before the Surgical Section of the New York Academy of Medicine. The same paper, somewhat rearranged, was next read at the Sixteenth Annual Meeting of the American Association for Thoracic Surgery at Washington, D. C., in May, 1933, and was published in the *Journal of Thoracic Surgery*[2]; and finally Lilienthal mentions the procedure in his paper, "Pulmonary Tuberculosis, Recent Types of Operations."[3] The use of the procedure goes back, however, to the early part of 1932 when, for the first time, it was introduced in our institution. A critical study of the first two papers mentioned, with especial reference to the discussions by O'Brien and Alexander, will convince one that, because of the general way in which the subject is taken up by Neuhof, and the lack of demonstrative figures, much is left to one's imagination regarding the nature and value of the procedure. Since end-results are now available in all but one of the patients subjected to this operation, I believe it may be of interest to present the subject in detail in the hope than an evaluation of the procedure in conformity with the facts may be gathered.

Table I

Cavity closed—sputum negative	6
Considered surgically completed, cavity reduced in size, but not closed—sputum negative	5
Requiring reoperation but general condition too poor to warrant it	2
Considered surgically completed, but have an open lesion with positive sputum	15
Deaths	3

In Table I are shown, in outline form, the results in thirty-one cases of pneumocavernolysis. One's attention is strikingly drawn to two facts, namely, the three deaths and the small number of six cases in which a satisfactory or anatomical result was obtained.† Two of the three deaths were due directly to the operation and occurred within

*From the Hudson County Tuberculosis Hospital and Sanatorium, Dr. B. S. Pollak, Medical Director.

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†By a satisfactory or anatomical result is meant x-ray evidence of a closed cavity plus negative sputum.

several days; the third death was due less directly to the operation and took place several months later. The detailed inquiry into these results and the causes of them will, I believe, be better appreciated by incorporating them in a discussion of the procedure.

This procedure, which for convenience may be termed Neuhof's operation, embraces two things: first, the rationale underlying the operation; and, second, the technic.

The former is expressed in the "principle of the exposure and investigation of the lesion"; by which is meant that after sufficient portions of the ribs overlying the lesion have been resected, an attempt is made to determine the location of the cavity, the nature of its wall, the surrounding pathologic condition, and the thickness of the pleura especially with reference to the probable interference it offers to collapse of the cavity. The questions which immediately come to one's mind are: first, whether this information can be ascertained by palpation with a degree of accuracy to justify the extra manipulation of the lung and its surrounding tissues with the accompanying shock to the patient; and, second, what is the comparative degree of accuracy between this method of obtaining information about the lesion and that derived from a careful clinical and roentgenologic study? The answer to these questions was made evident by postmortem studies and by the conclusions derived from a careful study of negative results with pneumocavernolysis. Thus in a series of twenty-five patients with fibrocavernous tuberculosis, the contents of each hemithorax were examined within an hour after death. Careful palpation was made of the lungs through the parietal pleura both while these were in situ and after they were removed from the thorax, in the attempt to determine the underlying pathologic lesions. The findings were recorded, and notes were then compared with the x-ray findings and the evidence obtained on gross serial sections of the lungs. Briefly stated, more or less pleural thickening overlying the lesion was found in every case, but in only one (where an old tuberculous empyema was present) was the pleura of such thickness as to resist release when freed from its costal attachments. Palpation of the lesion-bearing area of the lung through the overlying pleura or when that was dissected away gave conclusive information as to presence of cavity only when either a thin layer of lung tissue or none at all overlay the cavity. When, however, a moderate thickness of lung tissue (especially when infiltrated, as was usually the case) intervened between the cavity and the pleura, the presence of the cavity could not be detected. The nature of the infiltration, unless cheesy nodules were seen on the surface, could only be guessed at. As for the character of the wall of palpable cavities one could only speak of its thickness, but in no case, except on gross section of the lung, could one dissociate the changes in the wall per se and those in the surrounding lung parenchyma

which in the majority of the cases is responsible for the apparent thickness. Furthermore, with the lung in the thorax (as exposed by rib resection) palpation of the lesion-bearing area on all its surfaces is not possible, and this makes the analysis of the pathologic condition still more difficult.

Fig. 1. Fig. 2.

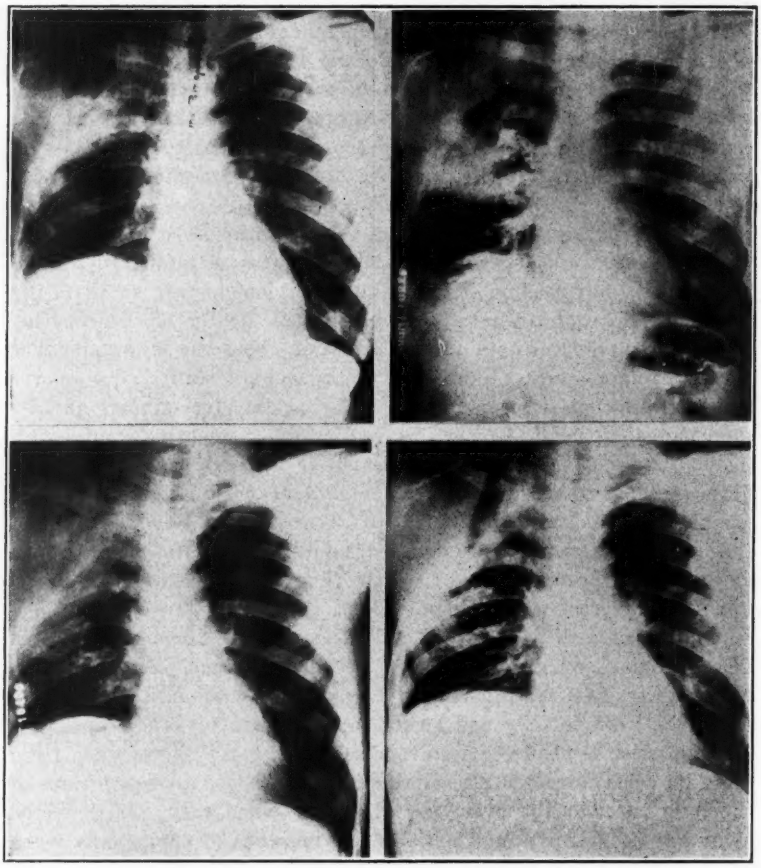

Fig. 3. Fig. 4.

Fig. 1.—Case 1. Taken one month after pneumocavernolysis. Note very limited partial resection of second, third, fourth and fifth ribs and dead space containing air and fluid overlying cavity, which is now tubular.

Fig. 2.—Case 1. Lipiodol level in cavity.

Fig. 3.—Case 1. After second stage of pneumocavernolysis showing no appreciable effect on cavity.

Fig. 4.—Case 1. Following third stage, showing some change in form but no appreciable collapse of cavity.

It was, therefore, no surprise to me to find that a careful clinical and roentgenologic study of each patient supplemented by bronchog-

raphy[4] gave information regarding the lesion and its location so far out of proportion in accuracy when compared with that obtained by palpation as to warrant entire disregard of the latter method.

Now, one need merely turn to the results of the application of the principle of exploration as a preliminary to pneumocavernolysis to find ample corroboration of the conclusions derived from autopsy observation. In about 50 per cent of the cases failure to close the cavity by the operative procedures resorted to was due in part to utilizing information derived from palpation rather than x-ray evidence as to presence and location of cavity. A concrete example is seen in Case 1 in which the preoperative film showed a slightly larger cavity in the right upper lung field than that seen in the immediate postoperative

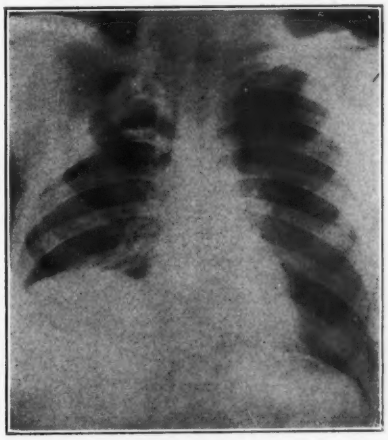

Fig. 5.—Case 1. Status of cavity after completion of third stage essentially the same as before pneumocavernolysis.

plate in Fig. 1. After removing sections between the posterior and anterior axillary lines of the second, third, fourth, and fifth ribs the exposed portion of the lung was palpated. It was decided that the cavity could not be made out. The reasoning was that if the annular shadow seen in the preoperative film was a cavity, its collapse was apparently achieved by the release induced by the limited rib resection. The wound was therefore packed snugly with iodoform gauze, and the operation was considered completed. It will be seen, however, that in Fig. 1 (one month after pneumocavernolysis) the cavity is still present. The interpretation of the cavity given to the annular shadow was accepted after a lipiodol level was demonstrated within the annular shadow as is seen in Fig. 2. A second and third stage failed to close the cavity as will be seen in Figs. 3, 4, and 5 for reasons which will be discussed later. In several cases one or two extra stages were

required because of insufficient length or number of ribs resected on the basis of evidence derived from palpation as to limits of cavity.

It seems to us, therefore, that information obtained by palpation is unreliable and confusing more often than not. It may have a place as a supplement to a careful roentgenologic study but should not take preference over the latter.

Fig. 6. Fig. 7.

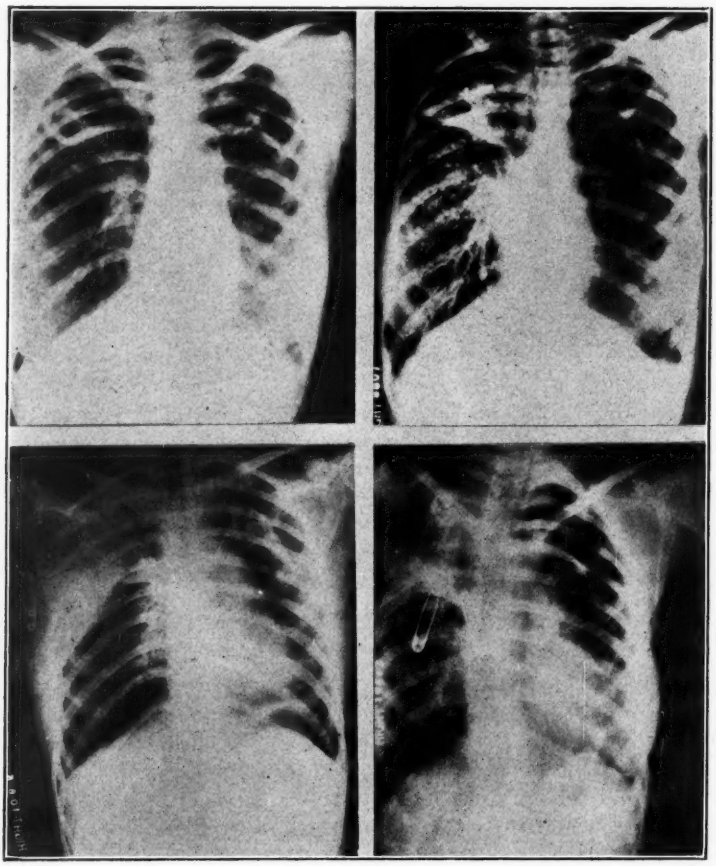

Fig. 8. Fig. 9.

Fig. 6.—Case 2. Before operation. Note partial effective pneumothorax on the left and a mixed infiltration in the first and second interspaces on the right terminating at the periphery in an annular shadow.

Fig. 7.—Case 2. Lipiodol level in annular shadow demonstrating cavity conclusively.

Fig. 8.—Case 2. Immediately after first stage of pneumocavernolysis. Note very limited partial resection of second, third and fourth ribs leaving first rib untouched, pack in wound displacing cavity toward mediastinum.

Fig. 9.—Case 2. After second stage. Note that in addition to further resection of second, third and fourth ribs there is included partial resection of the first and fifth ribs, but only slight reduction in size of cavity.

When the technical part of the operation is considered, many interesting features present themselves for analysis. First let us consider the degree of rib resection. It is, I believe, generally agreed upon that in the majority of the cases wherein collapsible cavities are encountered, closure can be achieved by releasing the tension on the lung. In pneumothorax this release is obtained by a reduction of the negative intrapleural pressure by a layer of air; while in thoracoplasty the same purpose is served by decostalization. Furthermore, it is the consensus of opinion that, because tuberculous cavities are usually situated in the paravertebral gutter, resection of ribs should be begun at the transverse process (and even include a part of the process) and continued forward to or beyond the limits of the cavity. Both the location and the number and extent of ribs covering the cavity can be ascertained from a good lateral roentgenogram. Finally it has been

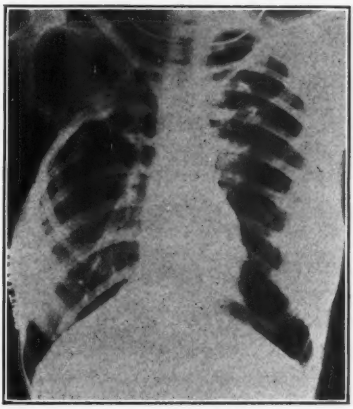

Fig. 10.—Case 2. Several months after second stage, showing cavity still opened, unappreciably changed in size and merely slightly displaced. Sputum still positive.

shown that the first rib, which serves as an anchor point for the thoracic cage, must be included in the decostalization.

This principle of release of tension on the lung by decostalization is more or less ignored in pneumocavernolysis, in which direct collapse of the cavity is sought. Resection of ribs serves primarily as an approach to the lesion, and may, therefore, be conservative or radical. Thus in Case 2, Fig. 1, will be seen a partial pneumothorax of long standing confined to the left upper lobe and an upper lobe lesion on the right. The annular shadow in the right upper lobe was thought by some to be a localized pneumothorax because of its clear-cut inner wall and because a pneumothorax had been present some weeks before. In Fig. 2 one sees a lipiodol level in this annular shadow, conclusively revealing a cavity. The cavity was considered superficially

situated and, therefore, easily approachable for direct compression. In Fig. 3 is seen the postoperative film in which one will note a very limited resection of the second, third, and fourth ribs in the axillary region (the first rib left untouched) and a gauze pack in the wound displacing the cavity inward. A second stage (Fig. 4) failed to affect the cavity because of the thickened, nongiving pleura produced by the pack. Finally in Fig. 5 one sees the cavity slightly displaced but still patent. It is evident that three factors are responsible for failure in this case:

(1) Resection of ribs was not carried sufficiently posteriorly to obliterate the paravertebral gutter.
(2) Insufficient number of ribs was resected.
(3) Thickened pleura, resulting from packing, served as a barrier for further release when a second stage was added.

Disregarding the last factor for the moment, one is impressed with the lack of proper decostalization with its accompanying limited release of tension on the lung; this in itself is sufficient reason for failure. While it is to be admitted that some cavities either because of size or thickness of wall or because of extent and character of surrounding infiltration may be uncollapsible, I cannot see the justification for such an assumption until after the surgeon has sufficiently freed the thoracic cage overlying the lesion.

Now, just as conservative resection is responsible for many of the failures to close the cavity in this series of cases, so radical resection takes first place as a contributing cause to the 10 per cent mortality. Of the three deaths, two were directly due to the operation. In the first case very wide portions of the upper five ribs were removed at the first stage, resulting in a marked mediastinal flutter and an aspiration tuberculous pneumonia in the lower lobe of the contralateral lung. Death followed ten days later. A similar phenomenon succeeded the first stage of the second case in which very wide sections of the upper seven ribs were taken, with death resulting forty-eight hours afterward. The third patient died several months after the operation. He, too, had a spread to the contralateral lung and a moderate mediastinal flutter after resection of wide portions of the upper four ribs at one stage.

Another feature of the operation is the packing against the partly released lung in the attempt directly to compress the cavity, with two major objectionable sequences: (1) production of a dead space; (2) excitation of a thickened pleura. In spite of the fact that removal of the gauze packing is carried out slowly over a period of several weeks, one finds, when the pack is finally out, a space filled with air over which the thoracic cage has regenerated. This is contrary to the belief of some that the space formerly occupied by the gauze is filled

in by granulation tissue. Gradually the air is absorbed and one finds that the lung has come out to meet the thorax, and with the re-expan-

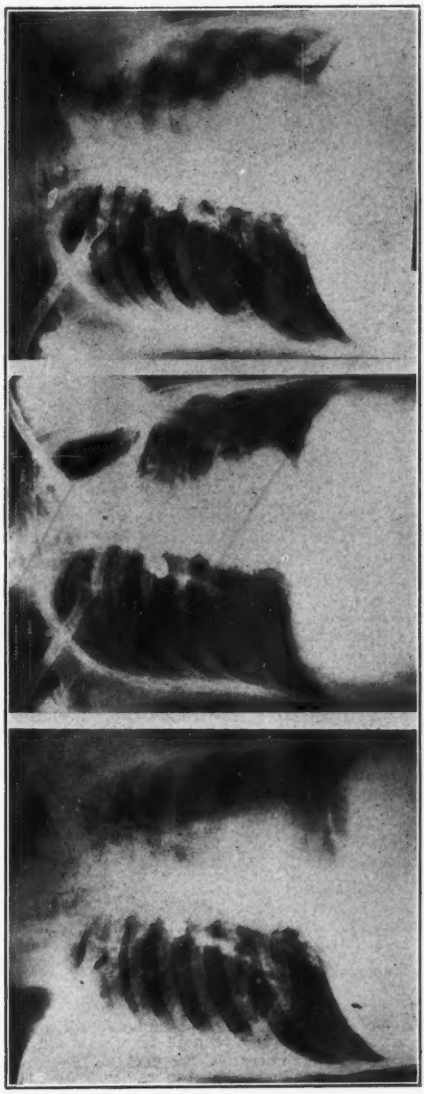

Fig. 11. Fig. 12. Fig. 13.

Fig. 11.—Case 3. Before operation. A large cavity is seen immediately below left clavicle in outer and mid zones.
Fig. 12.—Case 3. After pneumocavernolysis. Note large dead space containing air and the overlying regenerated ribs.
Fig. 13.—Case 3. Several months after operation. Note obliteration of dead space by expanding lung after resorption of air. The cavity has reopened and sputum is again positive.

sion of the lung the cavity may reopen. This is well illustrated in Case 3.

It is, however, to the thickened pleura resulting from irritation by the packing that one must attribute the greatest share for the failures

and morbidity. I found that the pleuritis following the first stage is marked, leaving a very thick pleura which resists further influence on the underlying lesion regardless of how extensive the decostalization is at subsequent stages. Thus in Case 4, Fig. 14, is seen a large upper

Fig. 14. Fig. 15.

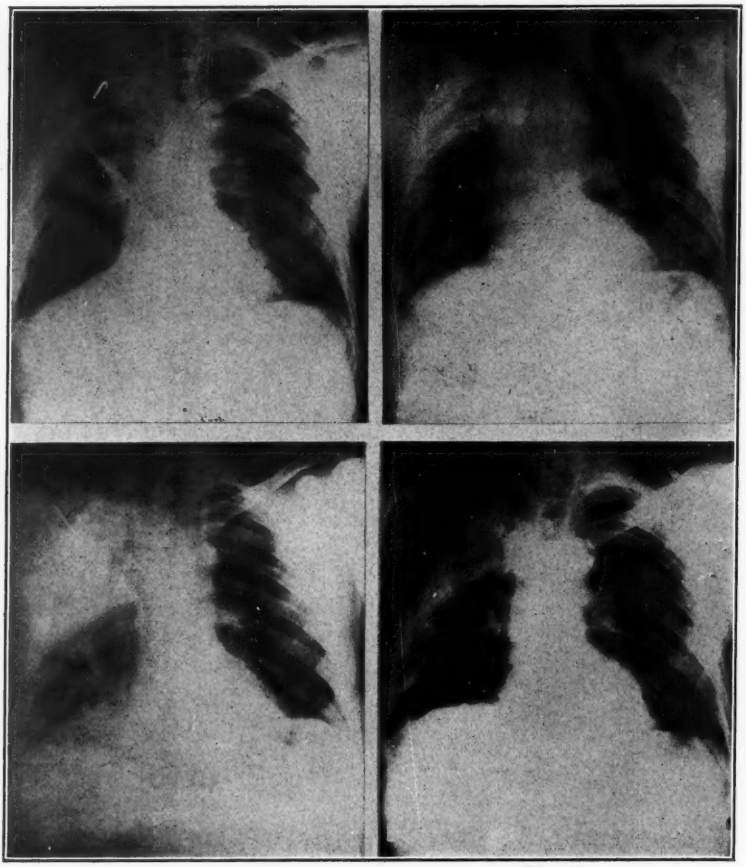

Fig. 16. Fig. 17.

Fig. 14.—Case 4. Before operation. Note large right upper lobe cavity uninfluenced by pneumothorax.

Fig. 15.—Case 4. Pneumothorax abandoned, lung reexpanded.

Fig. 16.—Case 4. Several days after first stage pneumocavernolysis. Note partial resection of first five ribs, pack in situ, cavity reduced to a wide slit.

Fig. 17.—Case 4. Several weeks after operation, the pack has been removed. Note the dead space containing air, a fluid level and the cavity reduced to a narrow slit.

lobe cavity uninfluenced by pneumothorax. In Fig. 15 the lung is fully re-expanded after the pneumothorax has been abandoned. The film in Fig. 16 was taken several days after the first stage and shows

the wound packed and the cavity reduced to a slit. Fig. 17, taken after the pack had been removed, reveals the dead space within which there is a fluid level, and the slitlike remains of the cavity. Finally, Fig. 18 shows the markedly thickened pleura overlying the cavity. It was felt that further removal of ribs could not influence the residual cavity because of the thickened pleura. The patient's sputum is still positive.

In addition to these major sequences of the gauze packing there is the circumstance that in every case the wound continued to drain for weeks to months, and in several cases cutaneous fistulas have remained

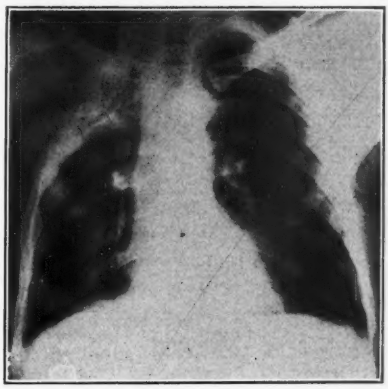

Fig. 18.—Case 4. Several months later. The cavity is still patent as a narrow slit. Note the markedly thickened overlying pleura. The sputum is still positive.

draining for over a year. Less objectionable features of the pack, yet requiring due deliberation, are:

1. The impression gained that the general resistance of the patient was decidedly lowered by the prolonged draining wounds.
2. The severe pain caused by the removal of the pack.
3. In several cases some of the packing was caught within the regenerated ribs and remained after visible packing was withdrawn, acting as a foreign body.

Finally a word should be said about lysis of pleura. The question that arises is whether interference with the pleura is necessary. I have already shown from recitation of the autopsy observations, that, except where a long standing empyema had existed, the pleura was not found so thickened as to interfere appreciably with release of the lung when its attachments to the thoracic cage were interrupted. Further proof of this lies in the evidence that in eight cases in which a partial wide upper thoracoplasty was performed without lysis of pleura, closure of the cavity resulted in six. Then, too, one finds on

careful review of the notes in the six patients in whom a satisfactory result was achieved by pneumocavernolysis that little or no lysis of pleura was practiced and that a wide upper thoracoplasty was the procedure modified only by the addition of packing. Lastly, it should be remarked that except in two cases a cleavage point could not be found, and one had to resort to cutting away of small pieces of pleura over the supposed site of cavitation, the sum total of which did not exceed one to two inches in diameter with most extensive lysis.

It is difficult to see how such a limited lysis could be of value even if the pleura did serve as an interfering influence to collapse of the cavity. It should, however, be understood that lysis is accompanied by a greater or lesser degree of shock to the patient and necessitates an unusually long period of anesthesia. That shock and prolonged anesthesia play an important rôle in interfering with a rapid and favorable convalescence is too well accepted to call for a discussion.

In summary it may be granted that the patients coming to thoracoplasty have tuberculous pulmonary cavities of long standing with changes within their walls and the surrounding pulmonary and extrapulmonary tissues which present many difficulties in one's attempt to achieve a closed lesion. Modifications in the conventional thoracoplasty, which appreciably influence results, have and will continue to be introduced. These changes must conform with the knowledge of the physiology and pathologic physiology of the thorax. The results with pneumocavernolysis, however, are such that the procedure is interpreted as an unsatisfactory modification of the conventional thoracoplasty.

CONCLUSIONS

1. Pneumocavernolysis is a new procedure devised for the collapse of tuberculous pulmonary cavities. It embraces the principle of exploration and palpation of the lesion, direct compression of which by lysis of pleura followed by gauze packing is attempted.

2. Localization and limitation of the lesion by palpation are fraught with a high degree of inaccuracy.

3. The principle which governs all forms of collapse therapy, namely, release of tension on the lung, is not stressed in pneumocavernolysis.

4. Lysis of pleura is rarely, if ever, required. The prolonged anesthesia which it necessitates and the shock that follows appreciably affect rapid and favorable convalescence.

5. Objectional sequences of the pack are the excitation of a thick pleura overlying the lesion and the production of a dead space, in which the resorption of the air later results in re-expansion of the lung, at times sufficient to reopen the cavity.

6. The thick pleura produced by irritation by the pack tends to serve as a barrier to any influence upon the underlying lesion regardless of how extensive decostalization is at subsequent stages.

7. End-results in 31 cases show a postoperative mortality of about 10 per cent and closure of cavity in just short of 20 per cent.

8. In view of these findings it is held that pneumocavernolysis is not a satisfactory modification of thoracoplasty.

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LIQUID LEVELS AND OTHER LIQUID SURFACES IN PLEURAL EFFUSIONS

A Study of Their Dynamics*

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THE upper border of pleural effusions has been the subject of much controversy, particularly during the last century when such eminent clinicians as Wintrich, Skoda, and Niemeyer were attracted by its peculiar line of flatness. Perhaps the earliest definite description is the curve of Damoiseau[1] which this author mentioned in 1834. Although Ellis[2] described his S-shaped line of flatness better known to us as the "line of Ellis" thirty years later, Garland[3] after a careful study of this subject credited Ellis with priority because of the latter's more accurate description.

To understand better the formation of the various lines of liquid surfaces, it is necessary to keep in mind the mechanisms of respiration.

During intrauterine life the lungs are in a collapsed or atelectatic state, the natural condition of these organs. With the first inspiration after birth, however, air rushes in and distends them, the condition thereafter present in normal life. Because the intrapleural pressure is relatively lower than atmospheric, the lungs remain distended. When, however, the intrapleural pressure is sufficiently increased, as in pneumothorax, by opening the pleura and letting air enter, the lungs collapse. This effect is not altogether explained by the increased intrapleural pressure.

It is easy to understand this phenomenon if we compare the distended lung to a distended balloon which collapses the moment air is allowed to escape. In both instances because of their elastic recoil they tend to collapse to the natural deflated state. Such deflation of course also occurs when liquid accumulates in the pleural space.

At the risk of appearing too meticulous I am here using the word liquid instead of fluid. Through common usage the word fluid has been used in medical English to mean only liquid. This, as we know, is inaccurate in scientific English, where fluid is regarded as a general term meaning liquid and/or gas. Because in thoracic diseases we so frequently deal with both liquid and gases it appears proper to me that we substitute for the word fluid its specific equivalents.

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The two liquid surfaces most familiar to us are the liquid level and the liquid curve.

The liquid level is generally recognized by a horizontal line of flat resonance and a dense horizontal roentgenographic shadow as visualized in a hydropneumothorax (Fig. 1-*B*).

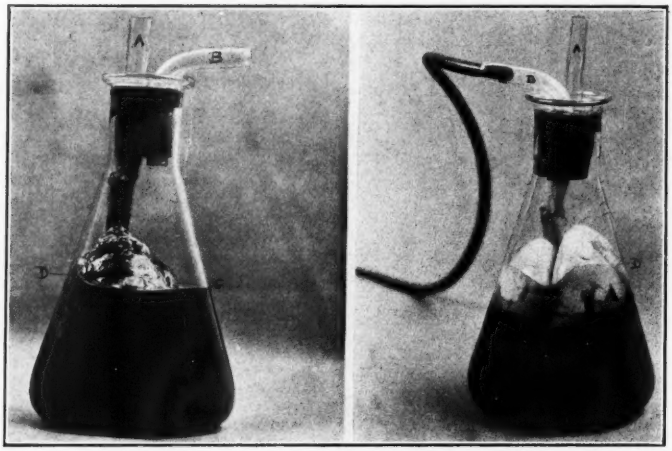
A. *B.*

Fig. 1.—*A*, Ordinary pleural effusion, right side. The effusion is recognized by a dense radiographic shadow curving concavely upward from the hilum to the sixth rib in the axillary line and by the haziness immediately above this shadow.
B, Hydropneumothorax. Same patient shown in *A* after a pneumothorax had been induced. Notice the separation of the lung from the chest wall by an air space. The liquid, which previously was displaced up to the sixth rib by the distended lung, has fallen below to the eighth interspace. Both the curved dense and the hazy shadows have given way to a dense horizontal shadow as a result of the separation of the lung from the chest wall.

The curved liquid surface is generally found in ordinary pleural effusions (Fig. 1-*A*). The curved line of flatness and the roentgenographic shadow are characteristic. The latter is found to curve concavely upward from the hilum toward the axillary line where it reaches its peak.

In ordinary pleural effusions, transudates and exudates where the curved liquid surface occurs, there is practically no gas present in the pleural space. In hydropneumothorax on the other hand it is the gas pressure that accounts for the horizontal liquid surface. The gas pressure, however, is not the complete explanation for this phenomenon, as shall be shown, since either horizontal or curved liquid surfaces can be produced experimentally in the presence of either high or low gas pressure.

In my experimental studies on the formation of liquid levels the use of glass containers made it possible to follow the development of different types of liquid surfaces. Negative and positive thoracic pressure



A. *B.*

Fig. 2.—*A*, Rabbit heart-lung preparation in a flask. One glass tube, *A*, communicates with interior of lungs through the trachea, the other tube, *B*, communicates with the interior of the flask. Both tubes are open. The pressure is atmospheric and the lungs are collapsed. A horizontal liquid surface or level is seen at *C* where the lung is separated by an air space from the side of the flask. A curved surface is seen at *D* where the lung is in close proximity to the side of the flask.

B, Same as in *A*, after diminishing the pressure in the flask to 20 cm. water by aspirating the air through tube *B*. This procedure has distended the lungs and so displaced the liquid upward. The curved surface *D* resulted when the lungs made contact with the sides of the flask.

effects were obtained by pumping air in or out of the containers. The pressure was measured by means of a water manometer.

In the first experiment (Fig. 2-*A*) a rabbit heart-lung preparation is suspended in an Erlenmeyer flask. The flask is partially filled with saline solution. There are two glass tubes, one (*A*) fitting into the trachea and admitting air into the lungs and the other tube (*B*) admitting air into the flask. The lungs are collapsed because of the atmospheric pressure surrounding them, and a horizontal liquid surface is present (*C*) as in a hydropneumothorax.

In the second experiment (Fig. 2-*B*) we have a repetition of the first except that some of the air from the flask has been aspirated through the rubber tube. This has resulted in a negative pressure similar to that in a pleural space. The consequence of this is an increase in the pressure gradient between the interior of the flask and the interior of the lungs, the lungs being thus distended, as in normal respiration, until they approximate the sides of the flask. Immediately upon their approximation, a column of liquid is seen to rise between the lung and the container. At some points the liquid rises higher than at others, producing an irregular curved line (*D*) with several peaks.

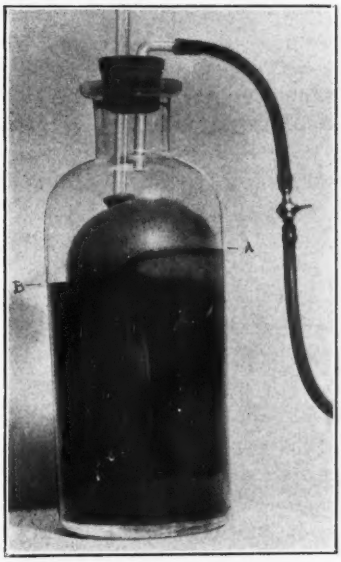


Fig. 3.—Balloon distended, as in Fig. 2-*B*, by diminishing the pressure in the bottle. Notice the curved liquid surface *A* where the lung is in close proximity to the side of the bottle. The side distal, which is separated by an air space, has resulted in the horizontal surface *B*.

It may be of interest to note that the lungs, although filled with air, do not float but dip deeply into the liquid. The submerged portion to a great extent inflates and deflates synchronously with the upper portion when appropriate changes in pressure are produced. This is an indication that respiration also occurs in the submerged lungs of pleural effusions.

In our next experiment (Fig. 3) we have an illustration of both a horizontal and a curved liquid surface in the same container. The rubber balloon shown here was inflated by diminishing the air pressure in the jar as in the previous experiment. Where the balloon is in proximity with the side of the jar a curved liquid surface is noted (*A*). A hori-

zontal surface is seen on the opposite side (*B*) where an air space separates the balloon from the side of the jar. In a hydropneumothorax such a horizontal surface occurs only in the presence of abnormally high pressure. In our experiment the pressure was relatively low (minus 20 cm. water), but the very same effect was reproduced at atmospheric pressure by directly inflating the balloon in the open jar. In our first experiment (Fig. 2-*A*) we obtained a similar effect with the collapsed lungs in a flask at atmospheric pressure. The side proximal to the flask produced the surface curve (*D*). On the side distal to the flask the horizontal surface or level formed as described. These experiments indicate that neither the high nor the low pressure so much as the air space separating the lung from the chest wall accounts for the horizontal liquid surface.

The liquid curves, as we have observed, occur only where there is close proximity of the lung and the chest wall. These curves are characterized by one or more elevations or peaks. Several forces may be said to be responsible for these peaks: (1) the pressure of the liquid itself, (2) the normal intrapleural pressure, and (3) capillarity.

In simple pleural effusions the liquid occupies the lower part of the pleural space because of gravity. As the liquid increases in volume, it rises and exerts a pressure on the submerged portion of the lung from all sides except from above. The more peripheral portions of the lungs because of the greater elasticity are compressed first. The hilum, on account of its greater rigidity and fixation, is least affected. In extremely large effusions the entire lung is compressed. It must be remembered that because of the natural tendency of the lungs to collapse, less hydraulic or pneumatic pressure is necessary to compress them.

The normal negative intrapleural pressure is important in elevating the liquid, through maintaining the lung in a distended condition. The submerged portion of the distended lung displaces the liquid upward, while close proximity of the upper part of the lung and the chest wall favors capillarity, so that the liquid is raised to a still higher level. The effect of these forces is illustrated in Fig. 1, *A* and *B*, representing the same case. In Fig. 1-*A* we see a simple pleural effusion with the characteristic dense curved radiographic shadow extending upward and outward from the ninth rib to the sixth rib in the axillary line. Fig. 1-*B* shows the result after inducing a pneumothorax. The lung is now seen separated from the chest wall by an open space, and the liquid has fallen from the sixth to the eighth interspace. If we should reverse this procedure, that is, aspirate the air of the pneumothorax, the lung will reinflate to its previous state and so displace the liquid upward to the sixth space. Such displacement occurs regularly in the lung-flask experiments (Fig. 2, *A* and *B*) by aspirating air from the flask. It is possible to bring the liquid to a still lower level than the eighth interspace (Fig. 1-*B*) by increasing the pneumothorax, in other words, by

diminishing the upward displacement of the liquid. It is well to notice the moderately opaque shadow above the dense curved shadow in Fig. 1-*A*. This represents liquid between the lung and chest wall. It is absent in the pneumothorax (Fig. 1-*B*) because the liquid has entered the open space created between the lung and the chest wall.

We must take note of a certain amount of cohesion existing between the two layers of the moist pleura. This is easily demonstrated when attempting to lift the lung from the chest wall. Its importance in resisting the upward intrapleural extension of the accumulating liquid is probably not very great because the liquid forms an entering wedge between the two layers of the pleura.

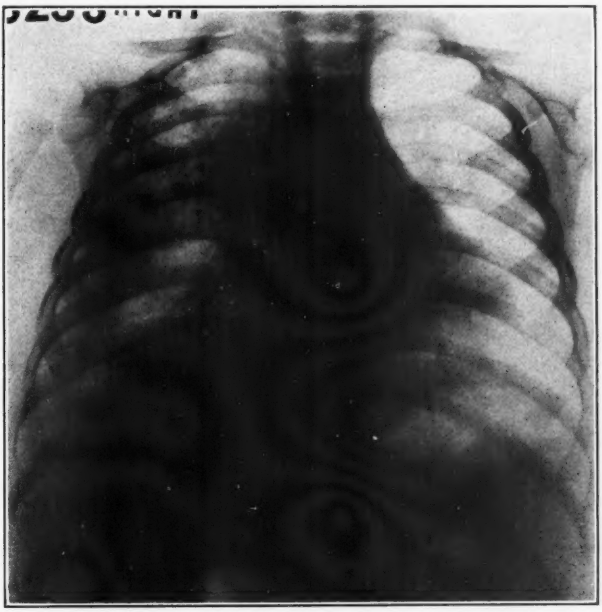


Fig. 4.—Empyema complicating lobar pneumonia, right side. Notice the vertical shadow along the side of the chest. This is explained by the rigid consolidated lung which has forced the liquid upward instead of yielding to its pressure below.

Capillarity depends on the proximity of the visceral and parietal pleurae above the region where these surfaces have been excessively separated by the effusion. In those regions where the two surfaces are in closer proximity to each other because of greater pulmonary distention, there is an increase in the height of the liquid. If we follow the curved line of the pleural effusion (Fig. 1-*A*), we will notice that the periphery of the lungs, which is most compressed by the liquid below, is also the region where the liquid ascends the highest. The reason for this is that the peripheral portions of the lungs are more elastic,

therefore are more easily compressed by the liquid below and more easily distended by the negative intrapleural pressure above. When the lungs lose this elasticity because of fibrosis or consolidation, the characteristic curved shadow may be missing. In pneumonia, for instance, when complicated by empyema, the effusion (Fig. 4) is recognized by a vertical shadow between the lung and the chest wall. This variation can be explained by the diminished resiliency of the consolidated lung which resists compression, the liquid, which ordinarily accumulates below, being forced upward between the two more or less rigid bodies, the lung and the chest wall.

The characteristic roentgenogram of a pleural effusion as we have observed is a concave curve extending upward and outward from the hilum toward the axillary region where it reaches its peak (Fig. 5-*A*). This peak, although not representing the highest elevation of the liquid, probably delineates the highest point discernible either by x-ray or by physical signs. It probably also corresponds to the highest point of the liquid in the translucent region to be described. The peak is most apparent in the axillary region because of the greater density of the liquid when viewed sagittally between the two layers of the pleura. A similar peak may be obtained in the anterolateral position viewed in this plane.

If we examine the film (Fig. 5-*A*) again, we will notice that the liquid surface represented by the upper border of the dense shadow begins at the junction of the hilum and the eleventh rib and curves upward and outward to the lower border of the seventh rib with its peak in the axillary line. The denseness of the shadow below the concave surface is due almost entirely to the liquid, the lung being pressed away. Above the dense shadow is an area of translucence which extends to the upper border of the ninth rib. Lung markings are visible here because only a moderate amount of liquid separates the distended lung from the chest wall. The opacity of this translucent area gradually diminishes from below upward, merging into the transparent area. The latter area represents the region above the upper border of the ninth rib. Here the lung markings are clearly visible with no indication of the presence of any liquid; nevertheless, as shall be shown, liquid is present in this area.

In our original experiment (Fig. 2-*B*) it was found that when the lungs approximated the walls of the flask a layer of liquid (*D*) ascended which appeared too thin to be detected in a thorax, either by roentgenography or by physical signs. To prove that such a thin film of liquid actually existed above the area of discernible liquid, 10 c.c. of a radiopaque oil (lipiodol and gomenol) were injected into a pleural effusion after a similar volume of liquid had been withdrawn. The patient was the one shown in Fig. 5-*A*. As was anticipated, the oil floated on the liquid, and so indicated the upper border of the effusion, which in this

case is limited by the thickened interlobar septum (Fig. 5-*B*), the lipiodol occupying the greater part of the eighth interspace. The transparency of this area (eighth interspace) in the plain film (Fig. 5-*A*)

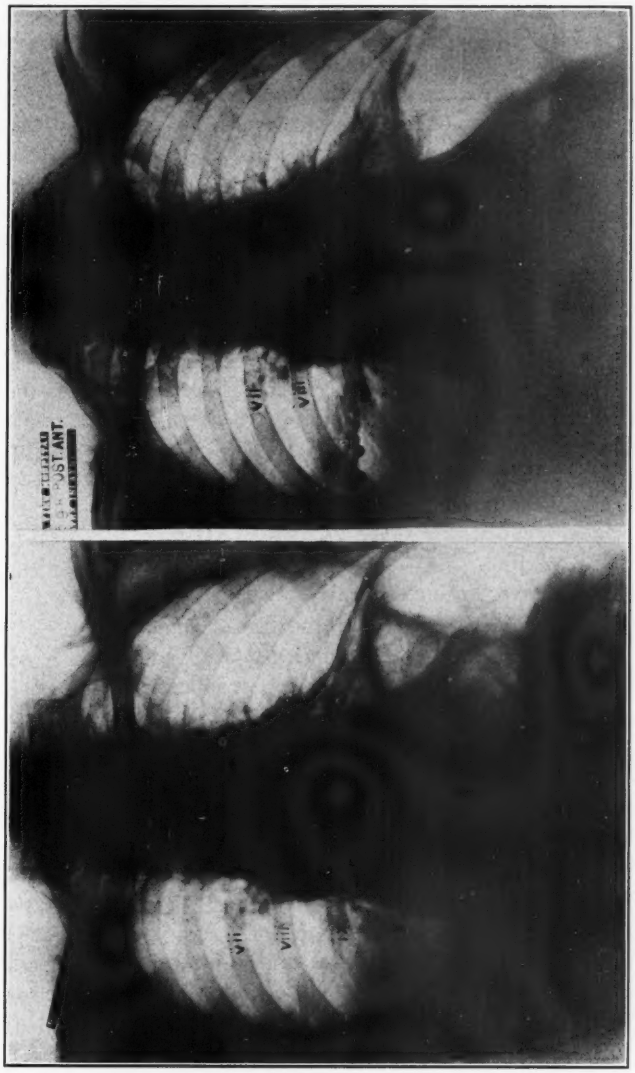


Fig. 5.—*A*, Pleural effusion, right side, showing the characteristic dense curved and hazy shadow. Notice for comparison with *B* the clarity of the eighth interspace.

B, Same as *A*, after 10 c.c. iodized oil had been substituted for an equal volume of serum. The radiopaque oil is seen floating up to the interlobar fissure, demonstrating the real height of the effusion and the presence of a film of liquid in the eighth interspace which is too thin to cast a radiographic shadow.

is proof that the layer of liquid here is too thin to cast an x-ray shadow. This upper layer is also too thin to interfere with normal physical signs.

We might then divide the simple effusions into three zones: (1) the lowermost or radiopaque area, made up of a large volume of liquid displacing the lung and casting a dense radiographic shadow; (2) the median or translucent area representing a moderate volume of liquid only slightly compressing the lung and casting a moderately opaque radiographic shadow; and (3) the uppermost or transparent area due to capillarity and representing a film of liquid too thin to cast a radiographic shadow.

In our experiments we employed balloons and lungs, each in containers of different shape. Because of the differences between their contours and elasticity, various types of liquid surfaces were obtained. The globular balloon, for instance, produced at the portion in close proximity to its containers a simple convex surface curve. In our first experiment with the lungs in the flask the lungs were collapsed, and a simple concave curve was produced where they approximated the flask. In the second experiment the distended lungs resulted in a rather complex surface curve, their snug fit in the flask precluding the presence of the large air space necessary for the formation of a liquid level as obtained in the other experiments.

SUMMARY AND CONCLUSIONS

Experiments were made, indicating that:

1. Curved liquid surfaces, characteristic of simple pleural effusions, result only when the lungs are sufficiently resilient and in close proximity to the chest wall. Changes in the resilience of the lung or in the contour of the chest wall can account for changes in the shape of the liquid surface.

2. Horizontal liquid surfaces, or levels, characteristic of hydropneumothorax, result only when the lung is sufficiently separated from the chest wall.

3. Increased gas pressure in a hydropneumothorax is important in the production of a liquid level only in so far as it separates the lung from the chest wall.

4. Liquid levels and liquid curves can be produced at either high or low gas pressure.

5. Expansion and contraction occurs in the submerged portion of the lung during respiration.

Three zones are recognized in simple pleural effusions, each merging with the other:

1. The lowermost or radiopaque area consisting entirely of liquid displacing the lung from the chest wall.

2. The middle or radiotranslucent zone, representing a moderate amount of liquid separating the lung from the chest wall.

3. The uppermost or transparent area, representing a film of liquid too thin to cast a radiographic shadow.

The word fluid, which is a general term, has been in this article substituted by its more specific equivalents, gas and liquid.

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REPORT OF A CASE OF CARDIOSPASM DUE TO DIAPHRAGMATIC GASTRIC HERNIA WITH ULCER*

Operative Procedure

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MOST cases of the benign variety of cardiospasm are curable by medical means and do not require surgery. The case before us first gave the impression as belonging to a malignant type. A thorough examination, however, revealed the true nature of the disease as being a cardiospasm due to diaphragmatic hernia with a callous gastric ulcer.

Inasmuch as these cases are very rare and their handling is quite difficult, we take pleasure in describing this case in detail, including also the medical and surgical procedures used.

J. S., fifty-one years old, reported that he had been complaining for the past four months of some difficulty in eating and frequently of more or less painful eructations of gas. During the last two months the symptoms had been more pronounced. He experienced more pain in the chest while eating and would wake up during the night with a sensation of tightness in his chest. At these times he would occasionally bring up some fluid and gas from his stomach and would then feel relieved for a while. He lost ten pounds in weight and a great deal in strength.

Concerning his previous history, the following is of importance: In February, 1928, the patient slipped and fell. At that time he had pains in his back (lumbar region) and was laid up for six weeks. In August, 1933, the patient lifted a beer barrel and felt pains in the epigastrium, which gradually increased. Occasionally there was some vomiting, especially after the first morning meal. Frequently while eating, he had to stop for ten to fifteen minutes, then he would bring up gas, and would be able to eat again.

Similar attacks, perhaps in a higher degree, existed at the time the patient was first examined.

Examination of patient on January 4, 1934, showed the following: Physical examination of the chest did not reveal anything pathologic. Palpation of the epigastric region right below the ensiform process revealed tenderness on pressure at this spot, and there was a feeling of indefinite resistance one to two inches to the left of the linea alba near the left costal margin.

The swallowing sound was once absent for over twenty seconds, but a few minutes later, when the test was repeated, it was present after ten seconds, but was broken and lengthened. X-ray pictures were made of the esophagus and stomach; they showed cardiospasm and some deformity of the stomach near the cardia.

At that time it appeared as though the patient was suffering probably from a cardiospasm due to a neoplasm of the stomach.

*Read by title at the Seventeenth Annual Meeting of the American Association for Thoracic Surgery, Boston, May 31, June 1, 2, 1934.

In order for us to make a more thorough study of the case, the patient was advised to enter the Lenox Hill Hospital. On January 18, the patient entered the hospital and was subjected to all necessary tests. The duodenal bucket string test showed that the cardiac and pyloric ends of the stomach were patent. There was bile at the end of the string and there were no blood stains. On January 19 the gastric contents were examined one hour after a test breakfast: hydrochloric acid, 30; acidity, 45; blood negative; few long bacilli. Blood count: 5,090,000; hemoglobin, 102 per cent; white blood cells, 6,000; polymorphonuclears, 65 per cent; lymphocytes, 33 per cent, eosinophils, 1 per cent; basophiles, 1 per cent. Urine, negative; Wassermann test, negative.

Inasmuch as the patient suffered a great deal of pain even after light nourishment, it was considered best to institute duodenal alimentation. On January 20 the duodenal tube was introduced; it entered the stomach after a short while. Feeding through the tube by the stomach was commenced right away. The next day the tube had reached the duodenum and duodenal alimentation was started. The patient felt very well all the time this method of feeding was practiced. All the distressing

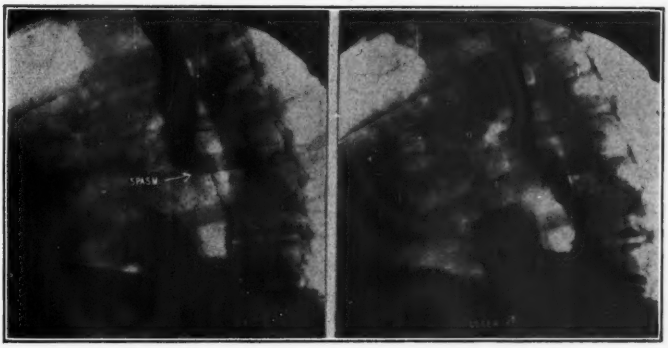

Fig. 1. Fig. 2.

Fig. 1.—Radiograph, February 6, 1934, showing cardiospasm and diaphragmatic gastric hernia of lesser curvature in front of esophageal opening.

Fig. 2.—Radiograph, February 6, showing diaphragmatic gastric hernia of lesser curvature in front of esophageal opening with ulcer niche at neck of hernial protrusion.

symptoms had then practically disappeared. The duodenal contents were examined in the fasting condition on January 23: light yellow; turbid; alkaline, 20; blackish crystals; mucus; A, 2; S, 1; T, 1. On February 4 the duodenal tube was withdrawn. When the patient began to eat by mouth, some of the former distress, although milder, reappeared. Another x-ray examination was then made in the hospital on February 6 by one of us (W. H. S.). The patient was first given the ordinary opaque meal. The stomach filled without apparent delay or defect at the cardia. There was a small, irregular shadow high up, near the left diaphragm, which was unexplainable. The patient complaining of dysphagia, and since the barium meal failed to outline the esophagus, barium paste was used. This showed the lower end of the esophagus to be somewhat dilated with distinct spasm at the cardia. There was retention of barium for a very perceptible interval. After the barium paste entered the stomach, there was found to be a pouch apparently of gastric wall on a level above the diaphragmatic dome. The appearance strongly suggested a diaphragmatic hernia with an egg-shaped pouch of stomach above the diaphragm. The material readily emptied from this gastric sac into the stomach below the

diaphragm. The stomach and duodenal bulb filled without any recognizable evidence of organic disease. The stomach was steer horn in type and transverse in position. At six hours the stomach was empty, the opaque meal being scattered through the terminal ileum and colon up almost to the splenic flexure. This was a case of herniation of the lesser curvature of the stomach probably through the esophageal opening. There had been considerable irritation at the cardia causing spasm, obstruction, and slight dilatation of the esophagus above. The small retention shadow at the cardia noted in the oblique position with the simple barium meal, though not recognized at the time, subsequently proved to be an ulcer crater at the neck of the hernial protrusion. (Figs. 1 and 2.) Pulse and temperature had been normal since admission of the patient to the hospital.

Reexamination on February 8 showed that the patient was a well-nourished, robust, stocky individual. There was slight resistance in the midepigastrium; no sensitiveness or rigidity. Liver and spleen were not palpable. Otherwise the examination was generally negative.

The patient was told that an operation would be required to relieve him of his trouble, the provisional diagnosis being diaphragmatic hernia of the cardiac portion of the stomach.

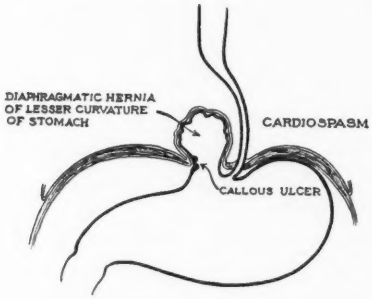

Fig. 3.

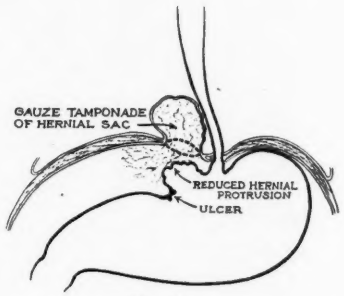

Fig. 4.

Fig. 3.—Condition found at operation, February 14. Hernia of lesser curvature of stomach through defect in diaphragm in front of and to right of esophageal opening, with callous ulcer at neck of hernial protrusion.

Fig. 4.—Operative procedure, February 14, showing reduction of hernial protrusion and gauze tamponade of hernial sac.

February 14 the operation was performed by one of us (Stetten) under nitrous oxide, oxygen, and ether anesthesia. A median epigastric laparotomy incision was made.

Findings: Patient was rather obese with a panniculus of about two inches in thickness and a very fat, thick omentum. Apparently the relatively small stomach was high up under the liver and diaphragm. Apparently to the right and in front of the esophageal opening was a circular defect in the diaphragm with hard, sharp, tense, rigid edges and with a diameter of about 2.5 in. In this defect lay rather firmly adherent a pouch of stomach springing from the lesser curvature just below the cardia. At the pyloric side of the neck of this pouch at the lesser curvature was a hard, indurated, circular area about three-quarters of an inch in diameter, which had all the appearances of the induration of a callous ulcer, and on careful palpation from the gastric side a definite circular crater could be felt in this area into which the tip of the thumb could be inserted. The crater is about three-eighths of an inch deep. (Fig. 3.) When this indurated area was withdrawn from the edge of the diaphragmatic hernial cavity, it could be exposed to view and was seen as an intensely reddened, somewhat umbilicated area just anterior to the lesser curvature.

It had all the characteristics of a benign lesion. There was no evidence of any enlarged lymph glands or other metastases. A small, firm, hard nodule, the size of a small pea, could be felt on the outer posterior surface of the spleen. The liver was normal in appearance and consistency. There appeared to be no other pathologic condition in the abdomen.

Fig. 5. Fig. 6.

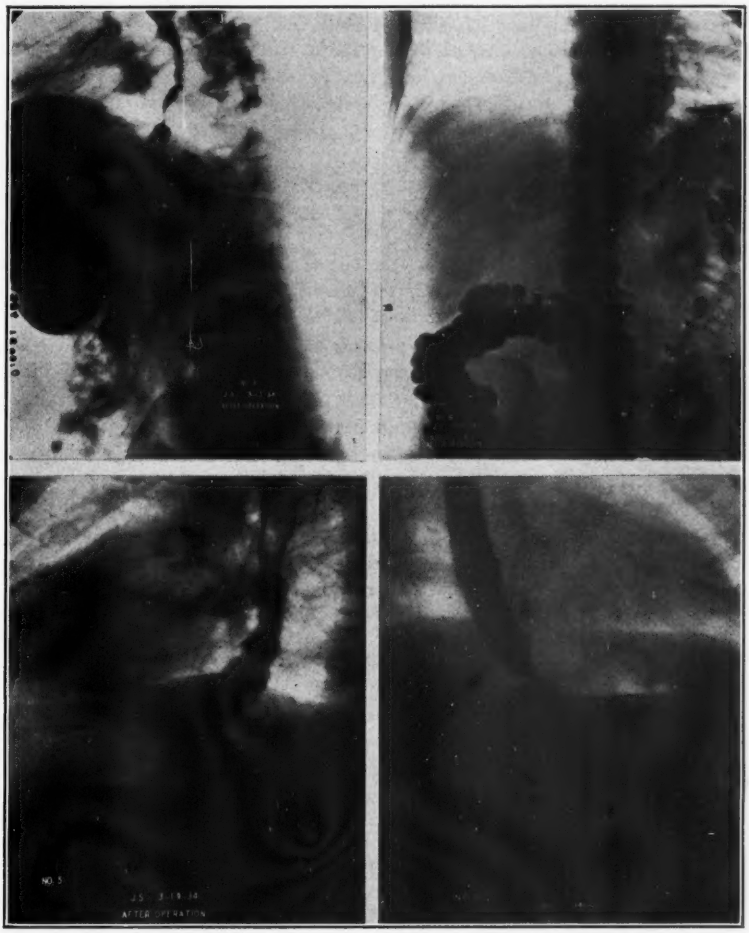

Fig. 7. Fig. 8.

Fig. 5.—Radiograph, March 13, showing condition found after operation with diaphragmatic gastric hernia of lesser curvature completely reduced, persistence of nipple of stomach at cardia, and also persistence of some cardiospasm. No evidence of ulcer present.

Fig. 6.—Radiograph, March 14, drainage sinus after operation injected, showing sinus tract and contracting cavity of hernial sac.

Fig. 7.—Radiograph, March 19, showing complete relief of cardiospasm and no evidence of diaphragmatic gastric hernia or ulcer.

Fig. 8.—Radiograph, April 12, fifty-seven days after operation, showing relatively normal conditions.

Reduction of Diaphragmatic Hernia of Stomach: By very careful manipulation it was possible to separate the adhesions holding the pouch of stomach in the diaphragmatic hernia and to reduce the hernia with the ulcerated area on the lesser curvature at the neck of the pouch entirely into the abdomen. The diaphragmatic opening was utterly inaccessible to suture from the abdomen, and the edges were so firm and rigid that even if it could have been reached it was doubtful whether the opening could be closed. Transthoracic exposure was deemed too serious a proposition for this type of case, unnecessarily risky and inadvisable. The cavity was plugged with seven gauze tampons to keep the stomach pouch effectually out of the hernial sac. (Fig. 4.) Tampons were surrounded with rubber dam. The usual closure was made of the abdominal wall in three layers with figure-of-eight silkworm-gut sutures through skin and fascia tied over rubber tubes, all drains being led out through the upper angle of the incision.

March 3: Patient had made an exceptionally uneventful convalescence. Dysphagia had been entirely relieved since operation. Tampons were loosened. Rubber dam and sutures were removed. Sutured portion of wound had healed by primary union.

March 4: Patient had a marked chill late the previous afternoon with rise of temperature to 104.2°. Temperature the morning of March 4, 99°. One gauze tampon was removed, and the others were loosened.

March 5: Patient's temperature previous afternoon was 102°. This morning temperature was 99°. Two gauze tampons were removed and the balance were loosened.

March 6 and 7: Afternoon temperature 102°.

March 8: Balance of tampons removed. Large rubber tube inserted into drainage tract. Afternoon temperature 102.2°.

March 9: Temperatures normal.

March 13: X-ray examination of esophagus and stomach showed that the gastric hernia had been completely reduced. There remained only a small, nipple-like projection of the stomach at the cardia similar to that which existed before the operation. There still appeared to be some spasm of the lower portion of the esophagus. The ulcer of the lesser curvature at the neck of the hernial protrusion found at operation was not demonstrable. (Fig. 5.)

March 14: The existing sinus was injected with bismuth and oil, and a roentgenogram showed the tract of the sinus leading up to the cavity where the former hernia was located. This cavity was gradually closing in. (Fig. 6.)

March 19: Drainage sinus was practically closed. X-ray examination of esophagus and stomach revealed considerable relaxation of the esophagus and relief from spasm to such an extent that a fairly normal outline was obtained. On the lesser curvature of the stomach, apparently high up, was a small budding defect which might be the original ulcer. (Fig. 7.)

Patient was discharged from hospital, cured, on March 19, with solid scar, and superficial, clean, granulating drainage sinus. Final diagnosis: Diaphragmatic hernia of stomach with callous ulcer of lesser curvature of stomach at neck of hernial protrusion.

March 22: Weight 172 pounds. Weight 180 pounds before operation.

March 31: Wound healed. Weight 176 pounds.

April 12: Weight 184 pounds. X-ray examination of lower esophagus and stomach revealed an apparently normal outline. There was no evidence of the diaphragmatic hernia, and all traces of the ulcer had disappeared. The cardiospasm was also relieved. (Fig. 8.)

REMARKS

With reference to the name "cardiospasm," Arthur F. Hurst,[1] of London, suggested the term "achalasia," meaning "failure to open" (or to relax) the cardia. This is true in some cases, but in the majority of instances we have to deal with a real spasm at the cardia. This applies especially to the beginning of the trouble, while later on, when the esophagus has attained considerable dilatation, the dysphagia will persist even if there is no spasm. The reason for this is that the redundant esophageal mucosa closes up the opening mechanically. Overstretching up to 80 or 90 F. causes a permanent opening to be kept up and thus facilitates the entrance of fluids into the stomach and the exit of air from the stomach upward.

The treatment remains the same, no matter whether the cardiospasm persists or not, as long as there is dysphagia present. Therefore, the term "cardiospasm" should be retained for all these cases of dysphagia.

The case reported in this paper is of particular interest. It shows the great importance of a thorough roentgen examination for establishing the diagnosis and the value of surgery to effect a cure.

The prominent symptoms of dysphagia of but short duration (three or four months), the absence of the swallowing sound at times, alternating with its delayed appearance at other times, and the constant presence of resistance to the passage of a bougie at about 15 in. from the teeth indicated cardiospasm, probably due to a beginning neoplasm of the stomach. The duodenal bucket string test showing that there was no real stricture at the cardia or pylorus, favored the same diagnosis.

For this reason duodenal alimentation had been instituted, and the patient was greatly relieved temporarily.

Bearing in mind the possibility of malignancy, another roentgen examination was decided upon. This time x-ray films revealed the diaphragmatic hernia as the probable cause of the cardiospasm. Etiologically a trauma (the lifting of the barrel) was probably the cause of the hernia. Fully aware of the impossibility of curing the patient in this instance by mere stretching of the cardia, surgery was recommended, and it was accepted by the patient. As described above, the operation was successfully performed, and the patient thus far is apparently cured.

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THE EFFECT OF PULMONARY DISEASE ON BLOOD GAS CONTENT*†

I. Effect on Plasma CO_2 Combining Power

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AS FAR as gases are concerned, the respiratory apparatus practically governs body metabolism, since there is no other physiologic provision for effective interchange of gases between atmospheric environment and blood stream. Therefore, any interference with respiratory function should be reflected in blood gas content. The two gases of major importance are oxygen and carbon dioxide. Under ordinary atmospheric and physiologic conditions all other gases or volatile substances assume a minor or inconsequential rôle. If, therefore, noteworthy changes are to be found, they should be sought in either the oxygen content or the carbon dioxide content of the blood.

In the series of clinical observations here reported, variations in oxygen content were disregarded and attention was directed only to variations in carbon dioxide content. In particular, the variations occurring during short periods of time were investigated, for although there is a wealth of experimental data to show the immediate effect of muscular activity on carbon dioxide content, there is little available information as to the variations during the period immediately following exercise or exertion.

It must be recognized that a great number of factors influence the carbon dioxide content or combining power of blood, among which are the source of blood (artery, capillary or vein), the CO_2 tension in the alveolar air, the CO_2 tension in atmospheric air, the rate and amplitude of respiration, the vital capacity, the heart rate and minute volume of blood, the chemical reaction of the blood, the lactic acid content of the blood, the hemoglobin content, and physical exertion. Absolute accuracy would demand coincident determinations of many of these factors. Experimentally, this might be done, but clinically it would be extremely difficult, especially in view of the frequency of the determinations. To offset this disadvantage, the conditions under which the observations were carried out were made as nearly uniform as possible. The chief variable then became the physical condition of the subject.

*From the Chest Clinic, Arnot-Ogden Memorial Hospital, Elmira.
†Material exhibited in part at American Medical Association Scientific Exhibit, Milwaukee, June, 1933.
Read before Saranac Lake Medical Society, November 1, 1933.
Received for publication June 2, 1934.

Each subject rested in an easy chair, without muscular exertion and without smoking, in a well-ventilated room, for thirty minutes. At the end of this period the first sample of blood was withdrawn. The subject then walked upstairs, without hurry, a height of fifty feet. As soon as the prescribed exercise had been completed, he was immediately again put at rest in the easy chair, under similar conditions, and the second blood sample obtained. Additional samples were obtained at five-minute intervals thereafter, for a period of thirty minutes. In all, eight samples were secured; one before exercise, seven after exercise. Invariably it was venous blood. It was always obtained from the arm. A tourniquet was lightly applied in the majority of instances while the blood was being collected. Between the collection of samples the circulation in the arm was in no way impeded.

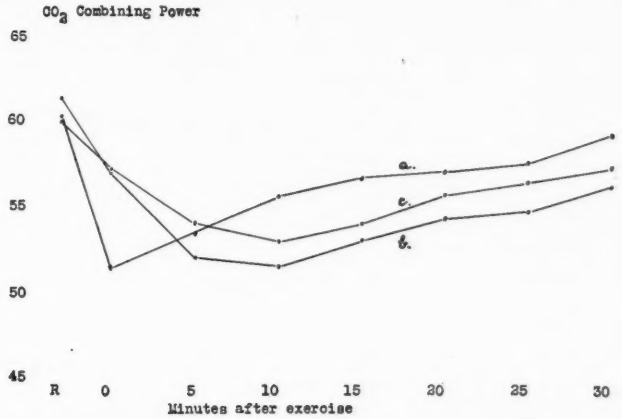

Chart 1.—The average venous combining power values obtained upon: (*a*) normal subjects; (*b*) patients suffering from nonthoracic disease; (*c*) patients suffering from some type of respiratory disease.

In one instance only were two series of readings made on the same individual.

In determining the CO_2 combining power the blood was promptly centrifuged, the plasma only was used, and the determinations were carried out on a Van Slyke apparatus. Since the combining power—not the content—was the value sought, no effort was made to collect the blood under oil inasmuch as the CO_2 content was to be equilibrated against the CO_2 content of expired air, but the determinations were completed with the least possible delay.

It has repeatedly been shown that the carbon dioxide content varies as a result of muscular activity. In the normal healthy individual there is an immediate drop in content, as well as in combining power, following exercise. It has also been shown that cardiac cripples often

exhibit a rise in content and/or combining power instead of a drop, following similar exercise. The fall of carbon dioxide content and/or combining power has been correlated with the rise of lactic acid content in the blood as a result of exercise. The exact variations during recovery from exercise are still obscure.

A total of twenty-eight observations were carried out on twenty-seven different subjects. Five subjects were healthy active volunteers in whom no evidence of disease could be found by physical examination or roentgenologic examination of the chest. Twenty-two subjects were chosen from patients—in eight the pathologic condition did not involve the respiratory apparatus—in fourteen there was a pathologic condition of greater or lesser extent in the respiratory tract (two ob-

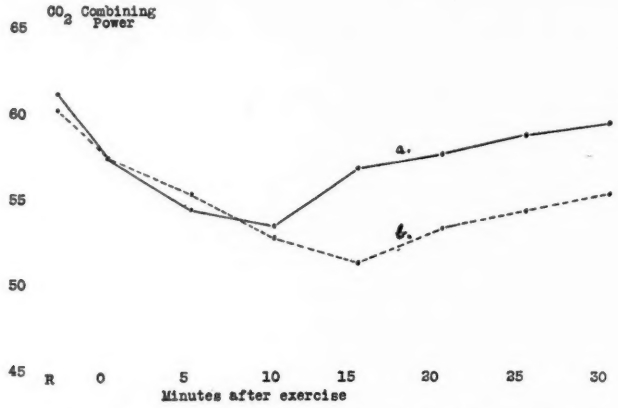

Chart 2.—The average venous combining power values obtained upon: (*a*) patients whose motor mechanism of respiration was crippled, but who were comparatively free from purely pulmonary pathologic condition; (*b*) patients whose motor mechanism of respiration was intact, but who were suffering from definite intrapulmonary pathologic lesions.

servations were made on one individual in this group). All subjects were ambulatory and, with one exception, able to take the entire prescribed exercise.

The five normal subjects showed marked differences in the plotted curves. The average values for the five are shown in *a* of Chart 1. In the group average it will be observed that the lowest value was obtained immediately after exercise, and that recovery took place forthwith with a measurable return toward the preexercise level at each reading. However, complete recovery was not made in the thirty-minute period.

Among the eight patients without respiratory disease were included the following cases: ulcerative colitis 1; diabetes 1; chronic cholecystitis 1; chronic arthritis 1; chronic nephritis 1; carbuncle, postopera-

tive, 1; myocarditis, mild, 2. All these subjects were found physically fit to undertake the required exercise. Four of them were gainfully employed and were only out of their usual work environment for diagnostic purposes. Three were unemployed, but felt able to work. Only one felt physically unable to work; this was a case of myocardial damage, and it is worth noting that his combining power continued to decrease throughout the entire period of observation. Again, wide differences in the individual curves were found. The average values of these eight curves are given in *b* of Chart 1. In this group the lowest determined value of the combining power occurred ten minutes after exercise, but the actual low point may be estimated, from

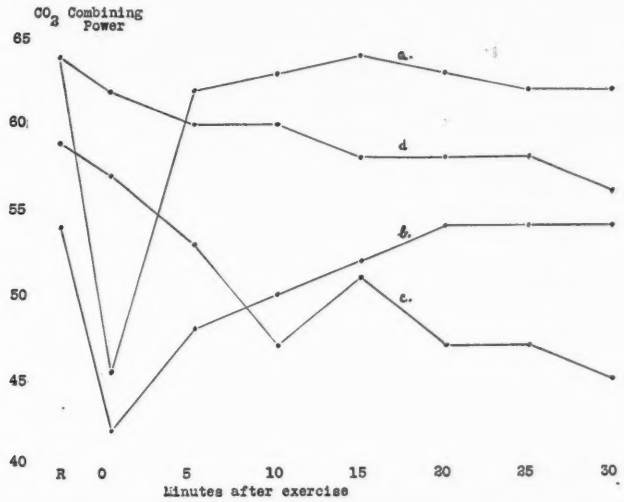

Chart 3.—The individual venous combining power values obtained upon: (*a*) a physically fit normal subject; (*b*) a patient four and one-half months after lobectomy, already engaged in light work; (*c*) a slightly disabled cardiac cripple; (*b*) a man who claimed total disability as a result of having been severely gassed during the war.

curve data, to have occurred approximately six minutes after the end of the exercise. Recovery, at the end of thirty minutes, was far from complete.

Fifteen determinations were made upon fourteen subjects with some form of pathology of the respiratory tract. The average values for these fourteen cases are shown in *c* of Chart 1 and very closely follow the average values for patients suffering from ailments not involving the respiratory tract. The lowest determined value was obtained from the ten-minute sample, and the estimated actual low point on this curve could be placed at seven and a half minutes after exercise.

The foregoing fourteen patients might be further divided into two subgroups dependent upon whether the disabling pathologic condition

merely crippled the motor mechanism of respiration, or whether it was distinctly intrapulmonary. If only those patients were considered in which the respiratory pathologic condition was extrapulmonary rather than intrapulmonary, and chiefly involved the motor mechanism of respiration, the average values did not show any great departure from the average values of any invalid (*a* of Chart 2). On the other hand, when the cases were considered in which the respiratory pathologic condition was definitely intrapulmonary, far different average values were obtained (*b* of Chart 2); the lowest determined value and the

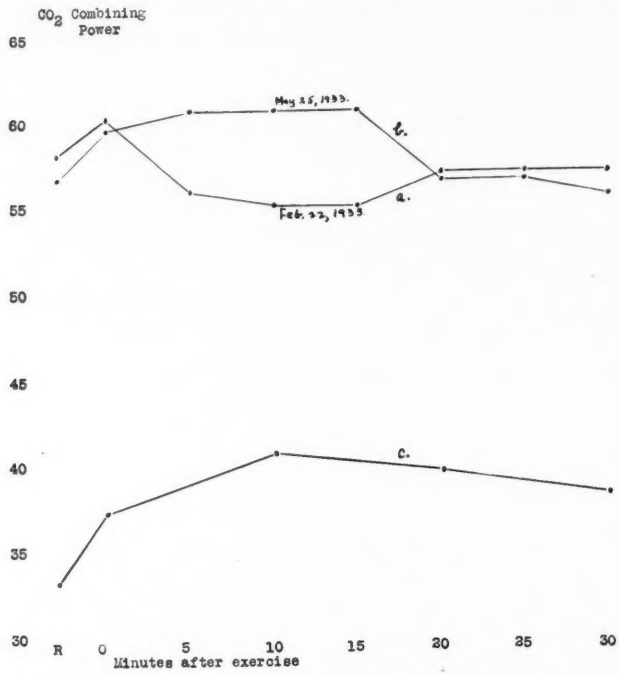

Chart 4.—(*a*) and (*b*) The venous combining power values obtained on different dates upon a patient recovering from extensive operation for lung abscess and exhibiting a progressive degree of "pendelluft". (*c*) The venous CO_2 content values obtained upon a man whose lungs were studded with metastatic sarcoma (see Fig. 1), and who became severely dyspneic upon slight exertion.

estimated actual low point both occurring fifteen minutes after exercise. This group included seven individuals, some of whom were employed in gainful occupations, and some of whom claimed to be totally incapacitated from all work.

Certain individual records deserve special comment.

Chart 3 *a* shows the curve obtained from a vigorous, healthy man, aged sixty years, who appeared to be younger, and who was found free from any evidence of disease. The outstanding feature is the very prompt return of the combining power to the preexercise level.

In Chart 3, *b* shows the curve obtained from a young woman aged twenty-six years, four and a half months after a right lower lobe lobectomy for tumor of that lobe. There was no other pathologic condition within the chest. At the time of the observation she was at work for a limited period of time each day, she was gaining weight, there was still a small residual bronchial fistula. The curve shows a prompt drop of combining power to a low point immediately after

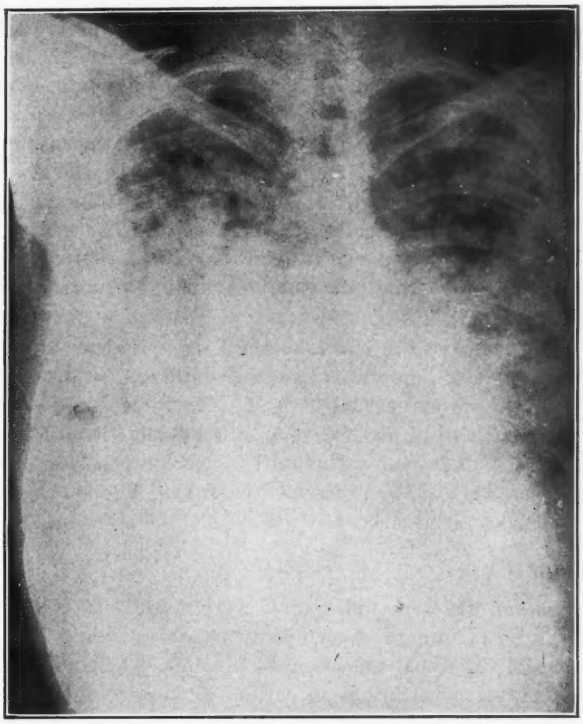

Fig. 1.—Roentgenogram of chest of subject from whom curve shown in Chart 4 *c* was obtained.

exercise, and a complete recovery to the preexercise level at the end of twenty minutes.

In Chart 3, *c* shows the curve obtained on a man forty-five years of age with an early coronary lesion. An electrocardiogram made at the time was normal, and the patient was classed as neurocirculatory asthenia. It was some months after this observation that he showed definite evidence of coronary disease. The outstanding feature is the progressive, though interrupted, downward drop in the combining power figures throughout the whole period of observation, coupled with the rapid fatigue of the man.

In Chart 3, *d* shows the curve obtained on a man thirty-nine years of age, who had been severely gassed in the war. This was stated as a fact on his service record. The man claimed to be totally disabled because of rapid fatigue. The outstanding feature is a progressive uninterrupted drop in the combining power throughout the period of observation.

In Chart 4, *a* and *b* show two curves obtained, at different times, on a man forty-four years of age, who had been operated upon for postpneumonic lung abscess and gangrene of a portion of the left lower lobe. An extensive operation had been carried out, and, as a result, an appreciable amount of left chest wall was without the normal support of ribs. This patient showed clinically the phenomenon of paradoxical respiration or "pendelluft." During the three months that elapsed between the observations there had been improvement in the condition of the wound, but, as the inflammatory reaction subsided, the degree of paradoxical respiration increased. The man was in no fit condition to return to work. Both readings showed very little variation in the combining power values and the last reading showed an inverted curve.

In Chart 4, *c* shows the curve obtained on a young man, thirty-five years of age, whose lungs were studded with metastases from a sarcoma originating in his left leg (Fig. 1). This record differs from the others in that it is in terms of carbon dioxide content of venous whole blood, collected under oil. The subject was intensely dyspneic and could take but half of the prescribed exercise. The curve is inverted to a very marked degree.

SUMMARY

Twenty-seven different individuals were subjected to the same exercise, namely, raising their own body weight a height of fifty feet, under as nearly identical conditions as possible. The study was limited to the comparative variations in carbon dioxide combining power of venous plasma at comparable time intervals. These variations were not controlled by any coincident determinations of lactic acid content, hydrogen ion concentration of blood or carbon dioxide tension of alveolar air, nor were they controlled by any determination of coincident changes in arterial blood. It must be realized that a study of gas values in arterial or capillary blood would shed vastly more light on pulmonary function than could be gathered from data secured on venous blood, which has been modified by body activities and conditions after pulmonary ventilation has produced its effect upon it.

It would be improper to draw sweeping conclusions from the present figures, and the study, therefore, can only be presented as a compilation of clinical facts that are suggestive and that shed a little light on the rapid variations that occur in the rest period immediately

following physical exertion. However, wide differences were found among these individuals, and it is proper to call attention to the relations between the plotted curves and the known or presumptive work efficiency of the various subjects. It is also proper to call attention to the group averages. It would seem that the "fitness" of the subject was reflected in the speed with which recovery was commenced and concluded, or the degree of recovery which took place within the arbitrarily allotted time.

CONCLUSIONS

1. The carbon dioxide combining power of venous blood shows rapid, wide variations as a result of exercise and during the rest period immediately following exercise.

2. The character of these variations can be roughly correlated with the physical fitness of the individual.

3. As reflected in the average curve for healthy individuals, exercise normally causes a sharp immediate drop in combining power, followed by prompt progressive recovery the moment that exercise has ceased.

4. As reflected in the average curve for unhealthy individuals, there is a continued progressive drop in combining power values for an appreciable period of time after the cessation of exercise, with a slower recovery occurring later in the rest period.

5. The character of these variations does not of itself constitute a satisfactory test of pulmonary ventilation, as thoracic and nonthoracic disease give nearly similar variations.

6. As reflected in the average curve of those suffering from intrapulmonary disease, such pathologic condition causes a wider departure from the characteristics of the normal curve than does nonthoracic pathologic condition or pathologic lesion involving only the motor mechanism of respiration.

AN IMPROVED THORACOSCOPE WITH ELECTRODES FOR THE DIVISION OF INTRAPLEURAL ADHESIONS*

JULIAN A. MOORE, M.D.
ASHEVILLE, N. C.

IN A recent article[1] I reviewed the operation of intrapleural pneumolysis. I discussed the various instruments and methods used for the division of intrapleural adhesions as an adjunct to the artificial pneumothorax therapy for pulmonary tuberculosis. I expressed the opinion that the Unverricht thoracoscope was the best thoracoscope available, and that the electrosurgical method of dividing adhesions was superior to dividing adhesions by a galvanic cautery.

In my own experience I have felt the need of a thoracoscope that would give a larger and clearer field of vision than is given by the Unverricht thoracoscope. Upon my suggestion, the Liebel-Flarsheim Company had made for them by the American Cystoscope Makers, Inc., a thoracoscope which I believe is superior to the Unverricht thoracoscope.

This improved thoracoscope (Fig. 1) is 16 French in size, and the cannula used for the introduction of the thoracoscope or the electrode is 21 French in size. The Unverricht thoracoscope is 15 French in size and requires a cannula of 19 French for its introduction. This telescope is equipped with a sterilizable light cord and connector.

This improved telescope is equipped with an excellent lens system and gives a right-angled field of vision about 15 per cent larger than the field of vision of the Unverricht telescope. At the edges of the field there is slightly more distortion than is given by the Unverricht scope. The larger field of vision is a distinct advantage in that it aids in orientation and permits the operator to get a wider view of the operative field. When dividing an adhesion, the slight distortion at the edges is not noticed when operating, as the operator's attention is concentrated on the division of the adhesion, the view of which should be in the center of the field.

Until recently, the only electrodes available for use with the Unverricht thoracoscope were those designed by Matson.[2] I believe that Matson's electrodes are the best that can be obtained. However, they are rather elaborate and expensive and require a special bakelite cannula for their introduction. The combined expense of the Unver-

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richt thoracoscope and the Matson electrodes has caused a few men to adopt the type of thoracoscope that requires only one puncture.

At my suggestion, the Liebel-Flarsheim Company made a straight and a curved electrode following in general the dimensions and contour of the cauteries of Unverricht. Since they were made, I find that

Fig. 1.—The improved thoracoscope.

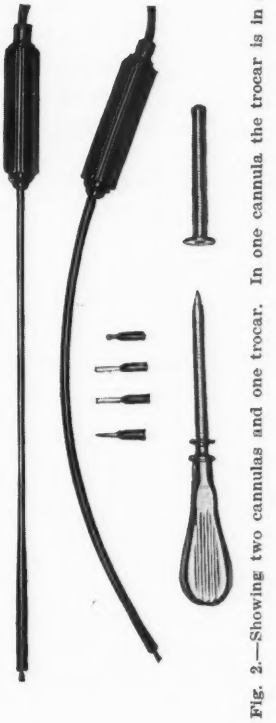

Fig. 2.—Showing two cannulas and one trocar. In one cannula the trocar is in situ.

the first electrodes designed by Matson were of a similar design, so I claim no originality for them.

These electrodes (Fig. 2) are simply but substantially made, and the curved electrode has all the advantages of manipulation of the curved cautery of Unverricht. They are rigid and will not bend on manipulation, and the insulation is more than sufficient to prevent a

short circuit between the electrode and the cannula. Two knives, one needle and one ball tip are supplied and can be attached to either electrode. The handles are corrugated so they will not slip in the operator's hand. The connecting cords are sterilizable by boiling if desired.

Two flexible cannulas and one trocar are supplied with the electrodes. The cannulas will admit either thoracoscope or electrode, a fact which will often prove of service, as not infrequently I find it desirable to interchange the instruments.

I have used this thoracoscope in the last four cases which I have done, and the electrodes in the last eight cases. I have found them to be very satisfactory. While the electrodes are not so flexible as Matson's electrodes, I have experienced no difficulty in reaching and dividing adhesions located anywhere from the apex to the diaphragm. They certainly are as easily manipulated as are the cauteries of Unverricht.

In presenting these instruments to the profession I make no claims of originality. I present them as a simple yet satisfactory set of instruments for the division of intrapleural adhesions by the electrosurgical method. Finally, they have the distinct advantages of being American made and of being much less expensive than existing instruments.

Since this article was presented for publication I have used these instruments on fifteen additional cases and I have found them to be entirely satisfactory.

REFERENCES

1. Moore, Julian A.: Intrapleural Pneumolysis, a Critical Review, J. THORACIC SURG. 3: 276, 1934.
2. Matson, Ralph C.: Operative Collapse Therapy in the Treatment of Pulmonary Tuberculosis, West. J. Surg. 38: 662, 1931.

AUTOMATIC HILAR LIGATURE FOR LOBECTOMY*

DUANE CARR, M.D.
MEMPHIS, TENN.

AT THE second stage of the two-stage lobectomy described by Alexander[1] the hilum of the lobe to be removed is tightly ligated and the lobe is not immediately amputated. The hilar ligatures should be tied so tightly that the pulmonary artery and vein and the bronchus are completely occluded in order that dry gangrene will result. Sometimes the hilar tissues are so densely indurated that it is virtually im-

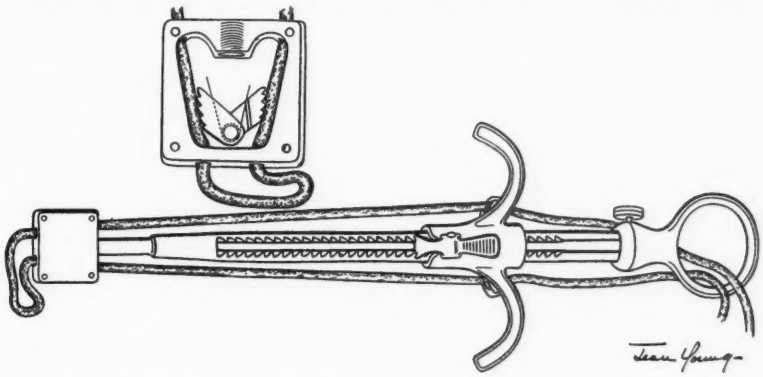

Fig. 1.—The instrument is shown with the ligature cord threaded through the flat mechanical head and fastened to the notched wings on the sliding grip, the loop being drawn almost closed.

Beginning with the sliding grip close to the mechanical head of the instrument, the large ligature loop (previously prepared by threading just the ends of the cord through the head with a straight needle) is slipped over the lobe to be removed and firmly drawn about its hilum. The loose ends are wound about the notched wings on the sliding grip, and the tourniquet is then tightened. When the arterial blood supply is definitely occluded, the ends of the cord are released from the grip, but left long for reapplication, if necessary. The shaft is unscrewed and removed from the head, which is left in place.

The modified Bethune lobectomy tourniquet handle of the instrument as manufactured is slightly different in design from the one illustrated, but is essentially the same in principle and has a long, ratcheted shaft to take up slack when the loop is tightened with the sliding grip.

Inset.—Diagram of the mechanical head showing the two pivoted ratchets being held by a small spring against the cord. These ratchets hold the ligature loop against the hilum as tightly as the loop is drawn by the sliding grip handle.

possible to tie a ligature by hand that will maintain complete occlusion of the pulmonary artery. In such cases wet, instead of the desired dry, gangrene results, and it is then necessary to apply another silk or rubber tube ligature so as to prevent continuing loss of arterial blood into the lobe.

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*From the Department of Surgery, University of Michigan.

†Manufactured by George P. Pilling and Son Co., Philadelphia.

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The instrument† that is described in this article was designed to produce complete occlusion of the hilar structures. The instrument has a two to one mechanical advantage to increase the force of compression applied to the hilum.

The mechanical construction of the instrument is illustrated in Fig. 1. Two small pivoted ratchets permit the ligature cord to slip freely in the direction of the handle of the instrument, but the ratchets immediately engage the cord when the direction of force is reversed. The ligature is, therefore, securely applied to the hilum with whatever tension the operator has applied to the mechanically efficient handle of the instrument. Since no knot needs to be tied to hold the ligature, there is no chance of its loosening. After the ligature has been applied with sufficient firmness and the ends of the ligature have been removed from the handle of the instrument, the handle should be unscrewed from the flat head, which is left in place until the lobe falls away at the line of gangrenous demarcation in the hilum.

Before using the automatic ligature on a living patient it was applied to the hilum of the lower lobe of fresh cadavers. The hilum, whose normal diameter is about 3.5 cm., was compressed to a diameter of from 0.7 cm. to 1.0 cm.; the tissues were not cut by the ligature. With the ligature in place it was impossible to pass a silver probe into the cut end of any of the pulmonary vessels or into the bronchi. The instrument was also applied to a common garden hose, and it completely shut off the flow of the full city water pressure. John C. Jones has used this instrument for a basal lobectomy and Alexander for a middle lobe lobectomy. Dry gangrene resulted in each instance following the first application.

I wish to record my acknowledgments to Mr. Albert Huntington of Ann Arbor, who constructed the original model of this instrument and whose suggestions contributed to its mechanical efficiency, and to Dr. John Alexander, whose interest and help have led to several improvements in its design.

REFERENCE

1. Alexander, John: Total Pulmonary Lobectomy, Surg. Gynec. Obst. 56: 658, 1933.

Department of Reviews and Abstracts

Conducted by Duff S. Allen, M.D., Associate Editor

Selected Abstracts

Goodwin, T. Campbell: Lipoid Cell Pneumonia. Am. J. Dis. Child. **48:** 309, 1934.

The author considers repeated roentgenograms the most valuable aid in the diagnosis of this form of chronic pneumonia, caused by aspiration. The distribution of the lesion is of the foreign body type resembling tuberculosis in particular, since many areas are so dense as to suggest calcification. Unlike tuberculous infection there is little enlargement of the mediastinal lymph glands. Caution is urged in the administration of oily preparations to weak infants and children.

Harry C. Ballon.

Scobie, Russell B.: Acute Asphyxia From Intrabronchial Rupture of a Tuberculous Mediastinal Gland With Recovery. Am. J. Dis. Child. **48:** 373, 1934.

In this most complete article upon the subject it is noted that over 90 per cent of the reported cases have occurred in children. Twenty of 87 patients were four years of age. Dyspnea, cyanosis, and stridulant breathing were the symptoms most frequently encountered. Atelectasis was suggested often as a possible diagnosis. Laryngeal diphtheria, foreign body, asthma, and enlargement of the thymus were also considered in the differential diagnosis. Tracheotomy and bronchoscopy are recommended to relieve the first asphyxial attack and to prevent secondary attacks. Paunz of Budapest (1922) has recommended the artificial rupture through a bronchus of caseous glands occluding a bronchus. He has successfully treated 12 such patients. He has also successfully aspirated the caseous material after the gland has ruptured into a bronchus. From personal contact with Paunz it may be stated that he has trained those in his clinic to be fully prepared and on the lookout for such cases just as Giertz has trained those about him to recognize embolism of the pulmonary artery.

Harry C. Ballon.

Colman, J. K., and Bisgard, J. Dewey: Congenital Aplasia of Costal Cartilages. Am. J. Surg. **25**: 539, 1934.

It appears that the fundamental defect which causes this deformity is a local disturbance of fetal chondrogenesis. The authors were able to collect eleven other cases from the literature. There are, as might be imagined, frequently associated deformities. In the reported case there were associated deformities of the ribs, muscles, shoulder girdle, and spine. Colman and Bisgard are of the opinion that these probably developed because of the alteration of function and the lack of support resulting from the absence of the cartilages.

Harry C. Ballon.

Grégoire, Raymond: L'oesophagoplastie préthoracique dans les Sténoses incurables de l'oesophage. (Prethoracic Esophagoplasty in Incurable Stenoses of the Esophagus.) Presse méd. **42**: 145, 1934.

An indication for a prethoracic esophagoplasty is unusual. The preparation and completion of an artificial esophageal apparatus are so time-consuming that it is useless to undertake the procedure in cancerous stenoses. A cicatricial stenosis refractory to dilatation constitutes the prime indication for the operation. Before undertaking the procedure it is necessary to appreciate fully the dangers of the initial operative stages, the technical difficulties that must be overcome, and the numerous revisions and retouchings that must be made.

The procedure consists in the construction of an artificial living tube which extends from the cervical esophagus to the stomach. Roux originated the procedure in 1907. For the construction of the new esophagus he used small intestine, large intestine, and gastric pouches with varying success, nearly all ending unfortunately. The risks inherent in the formation of a new esophagus when using abdominal organs as conduits influenced some surgeons to attempt the construction of the entire new tube out of thoracic and abdominal skin (Biercher and Giano). All those interested in esophagoplasty are now in agreement that it is too dangerous and too difficult to construct a new esophagus in one stage no matter what method or tissues are employed. It is infinitely preferable to construct the tube in two segments, the upper consisting in a cutaneous tube, the lower fashioned out of a loop of small intestine.

Grégoire reports in detail the case of a patient eighteen years old on whom he performed an antethoracic esophagoplasty for an undilatable cicatricial stenosis consequent to the swallowing of potassium chlorate.

The successive operative stages, not including the antecedent gastrostomy, were as follows:

First stage. Construction of a prethoracic tube skin flap.

Second stage. Laparotomy and exclusion, while retaining blood supply, of a loop of small intestine, 25 cm. in length, reestablishment of con-

tinuity of small bowel by end-to-end anastomosis. The isolated loop was then passed through the transverse mesocolon, brought out at the upper angle of the wound, and inserted beneath the antethoracic skin until its upper opening extended to the inferior limit of the cutaneous tube flap. The inferior opening of the isolated small bowel loop was then anastomosed to the stomach.

Third stage. The cervical esophagus was then brought out anteriorly and delivered through the skin of the neck. The distal end of the esophagus was then closed by two layers of sutures and left in the mediastinum.

Fourth stage. Anastomosis of the cervical esophagus to the cutaneous tube. Three attempts were necessary before a successful anastomosis was obtained.

Fifth stage. Anastomosis of the cutaneous tube with the superior portion of the isolated loop of small intestine. Six consecutive attempts were necessary before successful continuity was obtained.

The construction of the artificial esophagus thus required twelve operations and extended over a period of eleven months. Patience and determination on the part of both the surgeon and the patient are absolutely essential for this undertaking.

There are two dangers present in esophagoplasty: (1) peritonitis at the time of isolation of the loop of small intestine, and (2) mediastinitis at the time of delivery of the cervical esophagus through the skin of the neck. Numerous technical difficulties are encountered in performance of successful anastomoses between the cutaneous tube and the esophagus above and small intestine below.

Grégoire observed the following interesting functional result of the artificial tube. Deglutition was somewhat different for liquid and solid food. When the patient was in the erect position, the liquid column rapidly passed through the pharynx and cervical esophagus and was arrested momentarily upon arriving in the cutaneous tube. Successive deglutitions of fluid distended this tube into a fusiform pouch. When the quantity of fluid became large enough or the tension in the tube became great enough, the small intestinal portion of the canal was observed to go into peristalsis and then rapidly conduct the fluid into the stomach. Curiously enough the deglutition of fluids was done with just as much facility when recumbent as when erect.

The artificial canal at first did not function as smoothly for solid as for liquid food. Each bolus slowly passed through the cutaneous portion of the canal, pushed along by the succeeding bolus. Finally the tension of the column of solid food distended the cutaneous tube and the alimentary bolus then descended by external pressure exerted by the patient and by gravity (in the absence of contractions) into the small intestinal portion of the canal which rapidly propelled the mass into the stomach. This imperfection lasted for only a few months after which

time the patient was able to swallow without exercising pressure on the cutaneous portion of the tube and had a completely successful artificial esophagus.

Maurice Berck.

Fredet, L.: L'origine des abcès froids de la paroi Thoracique; leur traitement rationnel. (The Origin of Cold Abscesses of the Thoracic Wall; Their Rational Treatment.) Bull. Acad. de méd. **108:** 1635, 1932.

This article reaffirms the views previously published by Fredet and his pupils on the pathogenesis of cold abscess of the thoracic wall. The operative experience of Fredet is based upon 66 cases of thoracic wall cold abscess. This surgical pathological experience has demonstrated that tuberculosis of the parietes does not originate in the ribs or sternum, but always arises from the interior of the thorax. When bone is involved, it has been affected secondarily. By far the most common etiology is tuberculous adenitis of the internal mammary chain of nodes.

The rational treatment therefore is not to content oneself with removal of bone (which is but secondarily involved), but to attack the underlying deeply situated original lesion. This means excision of the tuberculous adenitis.

Cold abscess of the parietes exists in three situations:

1. Anterior, arising from adenitis of the internal mammary nodes.
2. Lateral, arising from nodes along the superior aspect of the diaphragm.
3. Posterior, arising from nodes lying prevertebrally. A tuberculoma of the pleura is extremely rare as the initial lesion.

The operative treatment consists in a wide exposure of the original adenitic lesion and involved bone; with total excision of the lesion and suture of the wound if the lesion is small, and excision plus gauze tamponade without suture if the lesion is large. The pleura in contact with the lesion is usually healthy.

Maurice Berck.

Klages, F.: Ergebnisse der Behandlung des kindlichen Pleuraempyems mittels Rippenresektion und Geschlossener Drainage. (Results of the Treatment of Empyema in Children by Rib Resection and Closed Drainage.) Zentralbl. f. Chir. **40:** 627, 1933.

Empyema in infancy carries a high mortality. The German statistics of Paschlau and Lehmann show a mortality of 56 per cent to 74 per cent for the first year of life, 24 per cent to 59 per cent for the second year, and 13 per cent to 17 per cent for the third year. Some authors have achieved better results, viz., Tonnis lost only three patients in a series of

61, and Klages now reports the following results obtained in Voelcker's clinic during the years 1926 to 1932. Ninety-eight patients in all were treated, with 7 deaths.

0– 1 year :	3 cases—1 death	
1– 2 years:	14 cases—2 deaths	10 per cent
2– 3 years:	13 cases—0	
3– 9 years:	58 cases—4 deaths	7 per cent
10–13 years:	10 cases—0	

Two patients were cured by simple aspiration and 5 others were treated by intercostal closed drainage. All the others received the following treatment:

Initially, to avoid mechanical disturbance, repeated aspirations for relief of tension were done until the pus became thick. This usually required five to eight days, occasionally even ten days. Operation was done in the sitting position and nearly always under local anesthesia, even in the very young. After an aspiration of verification, a typical costal resection was done and a small incision made into the empyema cavity. A tube was then inserted through this small opening, and the muscles and skin were hermetically sutured about the tube. The tube was fitted with a rubber flapper valve and drained into gauze maintaining partially closed drainage. The tube remained in place for twenty-nine days (average), the last ten days of which the drainage was "open" (not sealed off with gauze). Two cases of chronic empyema resulted in this series requiring partial thoracoplasty.

Thoracic and vertebral deformities were seen frequently in this series, but disappeared after a time under orthopedic treatment.

Klages states that he does not believe that the bacteriologic variety of the empyema bears any relationship to the gravity of the illness. In spite of this his statistics show only one death in 42 pneumococcal empyemas; whereas there were 3 deaths in 20 cases of streptococcal empyema and 1 death in 4 cases of staphylococcal empyemas.

Maurice Berck.

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Eighteenth Annual Meeting of the American Association for Thoracic Surgery

The Eighteenth Annual Meeting of the American Association for Thoracic Surgery will be held in New York City on Monday, Tuesday and Wednesday, June 3, 4 and 5. The hotel headquarters will be the Waldorf-Astoria. It is suggested that members of the Association and visitors correspond directly with the manager of the hotel for reservations.

The presentations at the meeting will be divided into two parts: the formal scientific program and the informal clinical demonstrations at the various hospitals and clinics in New York City. The entire program will be arranged so there will be no conflict between the formal program and the clinical demonstrations.

The scientific papers to be presented this year cover a wide range of subjects pertaining to surgery of the thorax. Several studies on the fundamental physiology of the respiratory and circulatory systems are to be presented.

The clinical demonstrations and informal discussions promise to be very instructive. There is a wealth of clinical material in the various hospitals, and this will be presented by unusually able men.

The final program will be published in the April issue of the JOURNAL OF THORACIC SURGERY.

Visitors who are interested in thoracic surgery are welcome to attend the meeting.